MANUFACTURING METHODS FOR PLASTIC MATERIALS

Paper presented to the Institution, London Section, by L. G. Chaffey.

CONSIDERABLE differences of opinion exist between plastic moulders as to what are the best methods of overcoming or avoiding the many and varied difficulties which beset them and the impression an outside observer will form after a preliminary survey of the industry is that plastics is merely another name for confusion. This is partly due to its mushroom-like growth and also to the lack of trained engineers who have seen fit to specialise in this comparatively new industry. The writer will attempt to make a general survey of the manufacturing processes and equipment required for a moulding from the powder to the finished article in the shipping department and enlarge upon different stages in the process as far as his experience and time will permit. The latter condition is necessary for it is impossible to deal with each section of the subject as one would like in the time at one's disposal.

Upon receipt of an inquiry there are factors which must be considered carefully before committing oneself to a moulding. (1) Is the design suitable and, if not, can it be modified to suit the moulding process? (2) If moulded, will the component function as required, or, in other words, will it meet a certain specification? (3) Are the future requirements from a quantity standpoint sufficient to warrant the mould cost?

Design.

On the question of component design a few words of advice at this stage will not be out of place.

(1) Avoid internal re-entrant cores.

(2) Do not ask for unnecessarily fine limits. It is possible to obtain a limit of .002 in. per inch but plus or minus .005 in. is considered to be satisfactory generally.

(3) Do not undertake to mould or cut threads finer than 9 B.A.

(4) Design metal inserts so that they cannot twist round or pull out when in service. Diamond knurl the insert and/or cut a groove in it where it can be used as a key in the material.

(5) Use metal inserts where screws will not be stationary whilst the moulding is in service.

(6) Avoid sudden change in section.

(7) Keep a careful watch on the design from the mouldmakers' point of view, such as using raduised corners where a vertical or milling operation is to be done. Avoid thin webs or ribs where deep milling and polishing is necessary and allow taper or draw wherever possible.

(8) Do not call for deep small diameter holes at right angles to the line of pressure.

(9) Do not ask for cross knurling.

(10) Remember when lettering is required, it is easier and cheaper for the toolmaker to sink the letters in the mould, so giving letters in relief on the moulding.

Specification.

As far as specification is concerned, the powder manufacturers publish full details of the physical and chemical properties of correctly moulded articles from their various grades of powder. Consequently it is a very easy matter to find out if there is a grade of material which will comply with your specification, so long as you know what you want.

Description of Processes.

Before proceeding with detailed descriptions of plant, moulds and operating methods, it would be as well to describe briefly the fundamental principles of the two types of processes. These are thermo-setting, and thermo-plastic. Under the first heading fall such materials as bakelite, a phenol formaldehyde product which includes general utility materials and a very wide range of speciali purpose materils. Also there are other such materials as Mouldrite P.F. and Rockite. Also under this heading fall the Urea Formaldehyde group such as Mouldrite U.F. and Beetle. Under the second heading of thermo-plastic come such materials as Cellomold, Trolital, Bexoid, and Diakon. However, for all these materials heat and pressure are the two essentials.

Themo-Setting Materials.

These are moulded in a hardened steel mould. A charge of powder is measured off by means of scales or measure. Alternatively, a

tablet or pellet is made to the required weight by binding the material together cold under fairly heavy pressure. These pellets can be made in a variety of shapes to suit the mould. This charge is then loaded into the mould by hand or by loading tray and the press is closed, varying speeds of closure being used according to the design of the component. The moulding is then cured or cooked at a temperature of approximately 340°F. for the phenol formaldehyde group and at 300°F. for the urea formaldehyde. This cooking time is proportionate to the thickness of the component and type of product, a very rough average being about half a minute per millimetre. This cooking or curing time is extremely important for high grade electrical or industrial mouldings as it affects the physical properties of the component if either overcured or undercured.

After the mould is opened the article is ejected by mechanical or hand ejectors or blown out by means of compressed air. Incidentally compressed air at about 60 to 70 lb. per square inch is more than useful for blowing flash and dirt from the mould, but use copper nozzles so as not to injure the moulds when the operator taps the mould to free the flash.

Thermo-Plastic Materials.

These materials can be pressure moulded as described for thermo-setting materials except for the fact that before the press is opened the mold must be cooled down in order to harden off the component before ejection.

Generally, however, the materials are injection moulded in the following manner. The material in a granular form is fed into a hopper and is then forced by means of a plunger into a heating chamber, is heated to a temperature of approximately 320°F. and afterwards forced by means of the plunger into a die which is kept cool continuously by water circulation. The material thus soldified in a few seconds, and extremely rapid production is obtained.

Plant.

A brief survey of the plant required for these processes is necessary in view of its importance coupled with that of the moulds. As has already been mentioned pressure and heat are the two essentials.

Thermo-Setting.

The heating medium for this method of production can be steam, electricity, gas or high pressure hot water. Any of these can be applied either directly to the tool or indirectly by means of platens

or plates upon which the tool is moulded. Opinions differ as to the best means of heating. Each has its advantages and disadvantages but considering things all round, the writer is of the opinion that steam is best.

Electric heating is clean, cheap, and pressures can be operated entirely separated from one another and as a separate unit. The disadvantages are that temperature control is not as accurate as steam, and also if one meets a moulding problem where a large semi-automatic mould requires cooling before ejection then steam heating is undoubtedly the only method worth while. With regard to gas heating, the chief advantage is low capital cost, but this is offset by other disadvantages such as the liability to local overheating, fumes, and invisible leaks. Hot water heating is comparable to steam and requires practically the same plant, except that the water is circulated round the system by means of a pump.

Various types of presses are used, but the majority are hydraulic. The supply of high pressure oil or water is supplied by a hydraulic pump through an accumulator which may be either of the weight loaded or compressed air type. The accumulator is necessary in order to smooth out the peak demands for high pressure water when a number of presses are opened at once and the demand exceeds the pump supply.

For a moulding the pressure required may vary from 1,000 lb. to 4,500 lb. per square inch of the projected surface area of the component to be made. This depends on the type of material, design of the moulding, and design of the mould. The main desirable features of a press are :—

(1) Robust design.

(2) Accessibility of packings.

(3) Accuracy of alignment of the moving crosshead, generally achieved by using bushes of ample proportions running on the columns.

(4) Simple but efficient valve construction, combined with convenient operating position.

There are on the market various types of self-contained presses which have their own hydraulic pump and so constituting single units, but, to be quite frank, it is generally only the consumer moulder who is able to afford these in a large shop.

Thermo-plastic injection plant is similar to the thermo-setting in that pressure is applied to close the mould, but there is also a secondary ram or plunger which injects the material into the die. There are the following types of machines : (1) Hand operated ; (2) hydraulic operated ; (3) compressed air machines ; (4) power operated.

The principle of operation of the presses is fundamentally the same. Just recently, however, great strides have been made in the design of really high production machines for this class of material. The heating used is generally by means of electric elements round the heating chamber, the temperature being varied by means of a rheostat and a pyrometer used for accurate control.

Mould Design.

This is a subject which is considered to be the most vital branch of the whole process, and undoubtedly the mould can be the success or otherwise of the job. A whole paper could be devoted to this section but the writer will do his best in the time available, and if it is borne in mind that his experience has been mainly to deal with thermo-setting plastics and that these were until now the most predominant, perhaps an excuse can be found for his giving more time to these than the thermo-plastics.

The number of impressions having been decided upon by estimating over a range of different sized tools—for example, from one to four impressions for a 5,000 per annum contract, for a moulding up to approximately 4 oz. in weight—the design of the mould must be carefully considered.

The leading factors to be borne in mind when discussing a mould design are as follows : (1) Number of impressions ; (2) type of mould; (3) method of heating ; (4) method of ejection ; (5) steel for construction ; (6) handling time when the press is open ; (7) method of loading material ; (8) type of material to be used ; (9) pressure necessary and where it will be taken when the mould is closed ; (10) whether the mould is to be a solid cut die from one piece of steel or made up by impressions mounted into a soft steel bolster ; (11) method of locating the punch with the die.

Number of Impressions.

Unfortunately the number of impressions cannot be determined by any known laws. There are too many variables to be considered, such as intricacy and size of the moulding and consequent tool cost per impression, required output per shift, curing time in the press, handling time when the press is open, and the size of contract over which the tool cost is to be amortized. The writer, however, after a careful study of these factors works out a range of prices for a given contract and by comparing the total investment for mouldings and moulds on each study, the most economic tool can be decided upon. It is generally found that this tool will meet most delivery requirements.

Type of Mould.

This is a problem which gives the designer a good deal to think about. Most thermo-setting moulds come under the heading of displacement dies. These can be either semi-automatic, automatic, or portable and, further still, each of these are divided into groups of different flash or trap design. The main point to be looked after with the choice of flash or trap design is that the mould does not have to make excessive flash or waste in order to make a full moulding. It will be found that with certain components the powder would rather escape from the mould than fill it up and make a thoroughly compressed moulding. To overcome this a trap is introduced where the punch meets the die and slides will demonstrate this at the end of the section. Automatic moulds are those which are fastened in the press and when the press is opened the moulding is automatically ejected ; semi-automatic moulds are those whereby the ejection is effected by means of the operator opening a valve for the ejector ram to come into operation. Portable moulds are lifted on to a bench or another press for ejection.

Method of Heating.

This has already been mentioned in the plant description but the mould designer, whatever the heating medium may be, has to decide on whether the die shall be directly heated or by means of a platen which in turn transfers the heat to the die.

Method of Ejection.

This calls for a considerable amount of experience, for often where one would like to place an ejector the customer has decided that no blemish or mark shall appear on the finished article. Also distortion may occur through not ejecting the article in enough places, and the writer can only say that these decisions demand careful consideration coupled with a fund of common sense and wide experience. Subject to the design being favourable, the draft or draw on either the top or bottom tool can be controlled in order to make the moulding come out on whichever part of the mould is desired. Sometimes a slight undercut is introduced near an ejector so that the component will hang on that particular part of the tool. Another method to effect this control is by means of a different temperature on the top to that on the bottom die.

Steel.

The ideal steel should possess the following properties : (1) Easily machined ; (2) be capable of taking a high polish after hardening ; (3) harden to give a scleroscope of about 80 ; (4) possess very tough core to withstand pressure ; (5) not distort or move on hardening ; (6) be of a reasonable price from 9d. to 1s. per lb.

This is no doubt a very difficult specification to accomplish but certain steel makers have laid themselves out to meet this end, and the writer is of the opinion that such steels as Jessops' G.1., if not completely satisfactory, are not far removed from success.

Handling Time.

This is very important from a cost point of view for it is the only period in the cycle of operations that is controlled by the human element. With semi-automatic moulds sometimes a part of the mould has to be ejected with the moulding and stripped by hand. Also certain components have inserts incorporated in them and this means time that the press is open. Consequently, concurrent with the design of the mould, jigs, gadgets, and fixtures other than the tool should be designed in order to facilitate handling. All this means careful planning. The writer often has fixtures like this made when the mould is in course of manufacture and sometimes finds that they are unnecessary when it is put into operation. This is because troubles which appear to be evident on the drawing board, sometimes have disappeared when the die gets into operation.

Method of Loading.

Another factor connected with the operation time is of course the loading of the powder or pellets. This can be done by hand but another method which is adopted for large or multiple impression moulds is the loading tray.

This consists of a tray with cavities on centres equivalent to the various impressions and a sliding shutter. The tray is loaded by the operator whilst his press is closed and the moulding is curing, and the powder is shuttered into the mould at the appropriate time.

Type of Material to be Used.

As you are aware, there are different grades of materials manufactured in order to give various chemical or physical properties. These have different bulk factors before moulding and consequently the cavity into which the material is loaded must be of sufficient size to contain the powder before moulding.

Pressure on Mould.

The pressure required for mouldings has already been discussed but it must be remembered that the mould should be capable of withstanding the effective pressure of the press when closed. The land or area of the die which supports the top tool when the mould is closed must be sufficiently large to take this pressure. The results of failure to comply with this condition are obvious. With compo-

nents that are not symmetrical and create a side thrust when being moulded it is as well to balance the impressions so that the side thrust is equal and opposite as far as possible.

Solid Cut Dies or Bolstered Impressions.

This is a question mainly for the mould maker and obviously the question of the most convenient design from a hardening point of view is an important factor. Also the question of cost has a bearing in making a decision on this point. Sometimes a solid cut die can be made much cheaper than a bolstered die by so arranging the impressions that there are parts of the mould which can be made common to two or three or more impressions. Another method to make the mould cheaper is to incorporate a common cavity for a number of impressions. This also sometimes shortens the loading time.

Method of Locating the Die and Punch.

This is more important on some mouldings than others and it is generally not wise to rely upon the press columns to act as the necessary location. Often, hardened and ground dowels and bushes of really ample proportions are used. Supporting the functioning of these the flash cavity can be used most effectively, in fact the writer often allows the dowels and bushes to be a rough location until the punch and die enter and then relies upon the trap design to take up the final location.

Transference Moulding.

At this point it will be worth making mention of the transference mould. This can be aptly described as a combination of both the injection and displacement principles. It has been used as far as the writer is aware only on phenolic thermo-setting materials. The material is placed into a cavity of the mould removed from the actual impression itself, and the top plunger, when pressure is applied, forces the material through gates into the mould proper. The advantages to be gained by using this type of mould are not at first apparent but where very delicate inserts, such as long thin wires are to be moulded throughout the length of a component, it can be seen that this method is to be very seriously considered. Unfortunately this type of mould has not been developed to any great extent but the writer is of the opinion that this is definitely a design of the future.

Manufacture of Moulds.

The writer proposes to deal very briefly with this subject not because it is not important, it is, but because it can be ruled as an

industry of its own somewhat divorced from the moulding shop. The mould designer, however, who has to be rather a versatile man, should interest himself seriously in this branch of the industry.

In the early days of the industry the mould maker had to be a good die sinker but machine tool makers have interested themselves considerably in recent years towards turning him into an operator rather than a craftsman. Such machines as the Keller diesinker and the Monarch Keller lathe are now well known and these machines now play an important part in mould production as do such machines as the Dekkel, Thiel, and Gorton millers. Jig-borers are also useful for bolster work and certain design moulds where centres of pins are important. The tendency to-day is of course to eliminate bench work and these machines are achieving their purpose. A good form turner is a useful asset as is also a man who thoroughly understands polishing. Another interesting process is hobbing. Do not confuse this with gear hobbing. Briefly, this consists of pressing into cold steel a master, which is a replica of the component plus shrinkage allowances, under high pressure—sometimes as high as 120 tons per square inch. The advantages to be gained in the manufacture of multiple impression dies by this method are obvious, but the technique involved is not sufficiently advanced to use this method as much as one would wish. In fact, the writer's advice is to choose your subjects carefully if you consider hobbing.

Finishing.

Finally we come to the finishing operations which are put on the mouldings before they are ready for the shipping department. When the moulding is pressed there is a thin film of bakelite attached thereto which makes the article unfit for use owing to its sharpness and ease with which it would cut the fingers. This has to be efficiently and effectively removed. Also finishing includes drilling, tapping, saw slitting, and such operations which have been found inadvisable to include in the moulding stage.

Most plastics can be drilled fairly efficiently by the use of special drills which have been developed with a slow helix angle, wide flute, and very narrow land. For machining operations tungsten carbide tools should be used.

To remove flash, rumbling is quite efficient on such mouldings as bottle caps. This can only be carried out when thin flashes are obtained. On larger mouldings, however, other methods have to be used. When the flash edges are circular or on the periphery of a round moulding, the component is generally rotated on a snug and a file or emery paper applied. Special machines for this purpose have been designed but the writer has found small bench electric motors to be quite effective.

With irregular shaped mouldings different methods have to be adopted. A skilful girl with a set of second cut files can achieve quite good results. Also a rotating file is useful for such components as telephone handles and this is comparable with an endless emery band running on two pulleys at about 12 in. centres for results. Other machines which are used are disc grinders and finishers.

Whilst special drills have been developed for mouldings, taps seem to have been rather neglected. The only special feature the writer has found is that of the quality of the steel. Bearing in mind that mouldings, especially of the thermo-setting type are particularly abrasive and hard wearing on the tools, it can be seen that a tap will soon lose its diameter. This of course is useless and one has to keep cutting taps back to retain their diameter. The average life of a tap before cutting back the worn portion is from 60—70 holes for a 4 B.A. thread $\frac{1}{4}$ in. deep.

Where considerable trimming is done on a moulding then it is desirable to introduce a polishing operation in order to eliminate the unsightly marks which are left where file or emery paper has removed the mould polish. This is carried out by means of polishing mops running at about 2,000—3,000 R.P.M. with a 10 in. mop. Various compounds are on the market for use as a polishing medium.

In conclusion, the writer would like to make mention of a few points which are worthy of note in connection with plastics. Do not attempt to over-tool or, in other words, be careful that the tools are not cumbersome with respect to handling times, for many otherwise well designed tools have contained too many impressions.

Remember that the variable cost of a moulding depends on two factors, first the number of lifts per hour which can be obtained from the tool and, secondly, the amount of finishing which has to be put on the moulding before delivery. Each of these factors depends almost entirely on the mould design and manufacture. Consequently the writer would impress upon you the importance of careful planning and mould design. Do not send a component drawing to a tool maker and ask him to design a tool. Plan the job carefully before it ever reaches him but do not think that, having so planned, all of your troubles are over. They commence when the mould is delivered.

Discussion

Mr. BLUNDALL: It has given me very great pleasure to come along this evening and listen to Mr. Chaffey. I certainly agree with him on designing, and it gives more satisfaction if the component designer and the tool designer get together with the shop foreman. I noticed his remarks about the tool maker sinking the letters in a mould, but, considering the hobbing operations, I think it is just as easy with the letters raised on the mould and sinking into the component. You cannot do anything in bakelite with the letters protruding because you get no colour. Opinion differs as to the medium of heating, but I find that the electrically heated platens are much more of an advantage than a disadvantage. You mention the polishing after hardening. I consider a polishing operation before hardening is essential, also the normalising, which, to my mind, is of great importance. If you blame the hardener for distorting your die he will tell you that it should be normalised, and as to-day you get a great demand for material it is so green it readily distorts in the hardening. I consider that pellets are not used often enough. This method is certainly a cleaner operation, and for feeding and loading the dies where you have got to have a multi-impression it is much more quickly operated, and certainly you have got the advantage of weight; pellets are very accurate to-day and there is no danger of overloading the compression. With regard to the handling time of the operator unloading, that does no seem to have much bearing because if he has got two or more presses working his time is absorbed by his other machines cooking. During the time that he is unloading and loading his mould his other moulds are cooking, which absorbs all his time. For tapping, you mention that you only get 60 to 70 holes without a regrind so I would certainly recommend chromium plating the taps when you would tap approximately 200 holes before a regrind.

MR. CHAFFEY: Regarding Mr. Blundall's remarks, I am afraid he has given me almost another paper to read. On the question of sunk dies, he mentioned the method of working. I thought I had made it clear that hobbing, in my estimation, has not advanced as much as it should have done. Frankly, in the London district hobbing is in the hands of two or three people, and instead of keeping them down to 200, 300, 400, or 500 ton presses, they have you messing about with a 2,000 press. The tendency of moulds is to increase in size and so hobbing has to increase in size. I remember hobbing 4 in. dial plates for the Debilio Radio some ten years ago. I have yet to see better hobbing. In other words, it has made no progress.

Nobody has spent money on developing this side, and I think that governs the matter of sunk letters and raised letters. Generally the letters are down at the bottom of the mould and not at the top.

I mention heating just as a matter of discussion and everybody falls out about it. I have had experience of electric heating, steam heating, and gas heating in three different plants. I only know that certain jobs I have done with steam heating I could not have achieved with electric heating—to wit, where you have to cool off to get the moulding out. By moulding I do not just mean the bigger type of moulding or the simple stuff, but the higher specification of industrial work, because that is really the future of moulding in my estimation ; and often to get a real good finish you have to cool down. You are at a very, very serious disadvantage with electric heating. I agree, electric heating is cheap, and I think I made that point clear in the paper.

Regarding the polishing of steels, I agree the polish has got to be put on the steel before it is hardened, but it must be polished afterwards. We do not use the moulds unhardened. The question of normalising—well, that is alright, but with some steels you can normalise them and still they move. I know quite a lot of them and you can normalise as much as you like and still they move, so I think that pulls normalising down.

With regard to pelleting, I am of the opinion that on certain jobs you can work very efficiently with the drum by the side of the press, and whilst the operator is cooking his stuff he just measures his powder out accurately into his loading tray, and the loading of the powder is as quick and easy as loading pellets in by means of a loading tray. You can have a loading tray for both pellets or powder. Frankly, I do not see much in it excepting that if you want to buy pellets from the powder manufacturers as pellets they won't guarantee them within less than 3 or 4%, and incidentally you are in their hands completely. Also some materials won't pellet. For instance, if you go on to micnro-film materials you cannot pellet it efficiently. It just won't hang together, no matter what pressure you put on it. On this question of handling time, you have touched on a very, very sore spot with me. The handling time of a job on the press is everything if you have got the press open. Assume, for instance, that you have just taken a mould out of a press and the operator is handling it on the bench. That press is open and its overheads are going on, and he has not another one in.

MR. BLUNDALL : I said that the operator was working two or three machines. Therefore he has got two dies absorbing his unloading and loading time.

MR. CHAFFEY : Yes, but that is bringing in another point. The company I am with have never favoured that method—or rather when I first went there I found one operator working on two or

three presses, and generally I found that the poor fellows were driven to distraction and if they fell into trouble with two or three jobs they were ready to chuck up the job. Give the operator one press and make that press work as much as it possibly can. The labour wages are nothing as compared with the overheads. And that is bringing in my point, have your handling times as quick as you can so that if the man is working a portable press, directly the die is out he is ready to put in another one. There is no object in having a battery of presses unless they are fully automatic. I have just heard of a full automatic press, but I have yet to see it press and I shall be very interested to see it. Then you are cutting your labour down, but frankly I would never cut my labour down on moulding.

Drilling and tapping chromium plating—I have never tried it, and I certainly will. It is obviously a method of tapping that the tapping people have not fallen to, and I am certainly falling to it. Our tapping bill is much higher than it should be for normal tapping procedure.

Mr. Hook: With regard to the method of hobbing you spoke of, do you hob with mild steel and have it carburized afterwards? Another point is, have you had experience of this drilling and tapping and small operations done by the operator on the side of the press? Is that quicker than having all these small operations done separately? Another point is about your mould steel which you say must have certain characteristics. I have never yet come across a mould steel that would take a good polish and that could be machined easily. I do not know whether Jessop's steel would do that. I should like to know.

Mr. Chaffey: With regard to hobbing, we were hobbing in iron, a much easier proposition I will agree, but I have yet to see equivalent hobbing on a 4 in. diameter job. We have hobbing jobs equivalent to telephone bases. We have found that the Keller Die Sinker is very quick and efficient for hobbing. With regard to operations by the side of the press. Do not give the operator anything to think about but the working of the press. You do not want to save labour tapping two or three holes or trimming. If he has a quarter of an hour to wait, then you can, yes, but efficiently. Do not delay your press for one single second and have it shot as quickly as you possibly can. That is the best advice I can give. With regard to polish—well, I don't know whether you noticed that slide of the very deep case in the side ram press, but those dies give a good polish. Everybody that looks at them says they would like to shave with them and asks whether they are chromium plated.

Mr. Jennings: I was rather surprised that during your discussion of the methods of moulding you did not mention pre-heating. I have found it very advantageous. Another point is, have you had

any experience in the injection of flame setting materials, such as bakelite ? There seems to me to be a very big field in that line. Thirdly, you mention about putting the impressions into soft bolsters. I do not think you quite stressed the necessity for having a hardened seam put at the bottom of the bolster. Fourthly, with regard to pelleting—if the job is fairly solid, yes. But if there are a lot of small pins, well you are just asking for destruction of the pins every time, because I have yet to see a metal which will take the heat quickly enough to become plastic before you have got pressure on the pins.

MR. CHAFFEY : I have had considerable experience of pre-heating, naturally, but to be frank I had to limit this paper. There are lots of operations that I could have put in—I am not making any excuse, but pre-heating is a very useful operation but rather overrated. I have had powder people advise me on a job, to wit, the big fellow there with a cable sticking out. I suppose it is without any proud boast—it is one of the highest technical moulds made in this country yet, as far as specification and intricacy of design are concerned. Well, with that I was advised to pre-heat when we were constructing the mould. Naturally I went to all my friends and they said : " Pre-heat. You will get round those pins easily and increase the flow up the sides." Pre-heating is just what we did not have to do. It was not the problem at all. The problem was to get it as cold as possible.

MR. JENNINGS : Frankly, I was not thinking of pre-heating with the idea of lessening the resistance on pins, but cutting curing time. We reduced the curing time from seven to five minutes and still got the same actual cure.

MR. CHAFFEY : For very, very thick jobs it is very effective, but you have to choose your jobs. With regard to the injection of flame setting plastics, I have tried using flame setting plastics or bakelite, to wit, in a bell mould, where it has made a certain amount of flash, but I found the trouble was that the stock, the equivalent of the injection stock, solidified and I had a terrible job in getting it out. When it had solidified we found we had to pull everything to bits. We dropped that method because we found it was easier to design metal in another way. I do not know whether there is any future in that at all.

With regard to the soft bolster and plate, the soft bolster is a carrier to the dies. I should explain that, I suppose. The dies have to be supported or carried and put in just the right position on the press. Well, that is done by the soft bolster, and you locate the dials, etc. The plate has to go on the bottom in order to take the pressure, if you have got the impressions coming on to a soft steel plate, but if you have got sufficient air at the bottom of your mpr ession to take the pressure you are putting on it and you have

got it on a cast iron plate you will not come to any harm. Generally, you get the sink in steel, not cast iron.

On the pelleting question, well, obviously pellets are generally rough on small pins. You should not attempt to use them. But as I said, with pellets you have to choose your subject. With pellets you can pre-heat them to soften them on the flow, but by the time you have messed about with pellets, why the pellets, at all, if you can get away with powder? The only thing with powder is that the operator may waste it.

MR. SCOTT: I wonder if you can give us any information on reinforcing? Is it done with fabric or it is possible to reinforce with metal in any way?

MR. CHAFFEY: Well, as I explained, it was too deep to go into all the various types of material that are being used, but you can reinforce the material. We were discussing it before the lecture—the question of shock proof. You get people coming to you and saying, "I want the thing shock proof." The reply to that is, "Yes, but how shock proof?" How high is high? I mean, what a specification to meet! How high is high? How shock proof? What has it to compare with? What shock has it to resist? You can use cotton for strengthening purposes, and then you go on till you get great big pieces of rag. But frankly it is a question of how shock proof. The person who wants the moulding should state this, and then the moulder can give him the impact figures. That is the way to get down to shock proof or shock resistance. These details and everything else are instituted for that purpose. Why not use them? To reinforce with metal—yes, it has been done. For instance, take the radiator cap of a car. I think one company has developed a certain material, they call it their elastic material, which is put round the inserts. One drawback is that you get a shrinkage of the material and you find the metal does not shrink, while the material does and cracks.

MR. SCOTT: Would that be so if the mineral was inside or just inserted in a line?

MR. CHAFFEY: Yes, but do not forget when you are inserting these strips of metal you have got to locate them in the die. But I would draw your attention to the simple method of reinforcing which is covering the die castings with the injection moulding press. That to my mind has a very, very big future. Mr. Jones could advise anybody after the lecture is over considerably with regard to this cellulose acetate side. My experience is not as wide as on the thermolics, but I have seen the methods that have been brought over from America for the first time and frankly I am getting quite anxious.

A MEMBER: With regard to the finishing of the moulding when it has been ground to remove the flash. It is then polished, I under-

stand, to restore the surface, but doesn't that spoil the protective surface of the mould? I have in mind the telephone handles that he referred to, and I have seen instances of those handles discolouring eventually due to the moisture of the hand, which seems to me to be due to the fact that the finish of the mould has been destroyed in removing the flash and then polishing again by means of buffing.

MR. CHAFFEY: Yes, well, actually whilst it is not altogether definite I think issues have really been found to your speech in the fact that the discolouring is not so much to do with destroying the surface. After all, it is the die that gives the colour to the article, and if that is impregnated right away throughout the filler and presents a full surface, well, it is going against the blow and you cannot get round it. But after grinding the surface you cannot get back the proper polish. On the moulding you cannot do it on the back obviously, and you do to a certain extent reduce the resistance of the original resin to the atmosphere and so forth.

MR. DUPEN: Can you give me any information or your opinion on the use of automatic instruments in this work particularly for sign control, instruments for controlling operations, and heating and cooling surfaces?

MR. CHAFFEY: Yes. As a matter of fact there are one or two people in this country who have automatic presses running to-day for the control of surface, but they are for particular moulds, incidentally. I have had very little experience of it. I have seen it done and looked at it, and it is very, very nice, but, frankly, we have not been able to afford it. There are companies which have instituted this press, and if it is up too long a bell rings, or if it is down too long a bell rings and so forth. It is all right. It is getting down to it. In the Sax machine—I think it is the Sax machine—that has come over from America you are able to control it by signals and know the amount it is open or closed and so on.

A VISITOR: Have you had any experience with screwed inserts which are not removable from the machine? The inserting is done automatically. The inserts themselves are threaded and the moulds are taken from them in the machine. You cannot take the inserts out. They are used for such things as small caps, bottle caps, etc.

MR. CHAFFEY: Yes, many years ago when we had machines for making tooth paste caps—I think Macleans were the forerunners with that, I am not sure—and we had machines where by turning a handle it rotates the screws and undid them, but very few people do it. We had an automatic machine and by turning one handle we were able to bring out three screws at a time or something like that. That is feasible. But we had visions of 36 and 40 impressions of tools up to 100 and 120, and unscrewing the whole die for us. It

worked, but I think that was about all. I do not know a great deal about it—possibly I have not been sufficiently in touch with that type of production.

A VISITOR: You think they may just undo the moulds and eject and undo them separately?

MR. CHAFFEY: Possibly when they operate the press automatically, the caps unscrew.

A VISITOR: It sounds rather slow, doesn't it?

MR. CHAFFEY: You do not have to put your hand in. You pull one die out. We do not make bottle caps now, but we used to have one tool out when the operator was unscrewing it, and the other die in cooking, and all you had to do then was to have the press open for about five seconds while the fellow at the back of the press pushed his die in and loaded the pellets and so forth.

A MEMBER: As regards this pelleting. Do you use the same process for moulding the material as for powder, or do you have to rely to a greater extent on the heating?

MR. CHAFFEY: Well, actually with shock resistance, I have found with the type of material which is rather a large fabric tool you generally drop your heat a little and breath as much as you possibly can without stiffening the powder too much. When you heat the material pre-heating softens it, but when you go on heating it you are tending to stiffen it. Well, you breath as much as possible. That is with XMB-199 which is a very large fabric shock material, I suppose about the highest there is, and that is the technique as far as I can explain it to you of moulding the shock proof material. Generally a lot depends on the thickness of the moulding, and the thicker it is and the lower the heat required. And breath as long as you can to get rid of the gas. Otherwise you get a tendency to blow up in blisters.

MR. HALLIWELL: I think this paper is the most interesting and constructive we have had on this subject for a good many years, and I read into it a condemnation of the portable mould, although no doubt Mr. Chaffey is going to tell us we shall always have it with us. But I have really only got up to ask Mr. Chaffey one question, and that is, can he tell us anything about the method of producing screwed components by the injection process on automatic machines? How do you get them out?

MR. CHAFFEY: I have got to confess a weakness there. Frankly, I cannot tell you. I think perhaps Mr. Jones could explain this adequately. I know that they can be unscrewed automatically, but when and where I do not know.

MR. JONES: We are, as a matter of fact, putting a machine through now with an unscrewing device on the die. The mould used in that case has a piston which injects the material and on one stroke it screws a circular gear round, screwing a number of smaller gears

through it in part of the internal part of the bottle cap, and on the return stroke the piston goes back again, and after they have been unscrewed the flat die moves backwards, carrying the caps with it, and it is ejected in the ordinary way from the screws. I think another way of doing the same thing is to have a small electric motor blow into the die, and this works on the gear.

A MEMBER : Has any use been made of materials of higher heat conduct for moulds, such as bronze or even aluminium alloys ?

MR. CHAFFEY : Yes, as a matter of fact on the mould that makes these beakers we use copper cores to transfer the heat from the platen at the back to the top of the punch, and so equal up the temperature as far as possible. That is one application, but there is another application which I think I did not mention. To be frank, I know very little about it. I want to know more about it, and all of us in the industry are in the same boat. It is with brillate copper. It is mainly an American development, I believe, and is copper to which is added duralumin, and you have your hardening properties and so forth, which have another advantage of being easily cut and then hardened and used for a mould. Well, that is one development about which I cannot discuss very much. I do not know much about it, but we do use pieces of copper and so forth for heat transference from one part of the mould to another.

MR. B. H. DYSON : The hobbing method of making moulding dies has been mentioned considerably, but with little enlightenment on the subject. My experience with this process, in contact with producing moulding dies for bakelite switch knobs as used in the radio trade is that it is a successful and economical method of producing multi-cavity dies with identical impressions. The process is one of displacing metal, and I have found it essential that the hob is correctly heat treated and polished and that the blank that is to receive the impression has a good surface finish and is relieved at the underside to allow for the metal that will be displaced. I was interested in the rumbling or tumbling process of removing the flash from mouldings and I should like to hear a little more detail on this regarding the methods used, because I rather visualise the mouldings being so damaged or broken and resulting more or less in it being an operation in which one reclaims the bakelite powder instead of getting fettled mouldings. Possibly our lecturer experiences the trouble that many producers of bakelite mouldings do and that is, that although we get a complete moulding out of the dies, it does not always end up as a complete moulding, very often lugs and bosses are broken off or damaged. Is there any method of " welding " bakelite or of building it up in any form, in the case of intricate mouldings such salvage would be valuable and I should be interested to hear of any such process.

MR. CHAFFEY : With regard to hobbing, that method of relieving

the bottom of the blank is one method. Obviously where you displace metal it has got to go somewhere, and it flows the same as anything else flows. You can see it sometimes in the form of bands on the top of the die and at the sides of the die. It flows and you have got to put somewhere for it to flow. If you turn a groove round the outside of the flattened tool sometimes it will go to that groove. I will tell you why that is often done, and that is because in relieving at the bottom of the blank sometimes you push the radio knobs, for instance, in and the bottom merely collapses. It does not flow, but if you turn a groove in the side of the blank it flows out.

On the question of rumbling—no, I do not think you get much breakage. You do not use any weights or shots or anything like that. You let the moulds rumble themselves. I have a problem now with a very little bush of about $\frac{1}{8}$ in. in diameter and about $\frac{3}{32}$ thick with a little tiny hole through it, and I am afraid I came a cropper over the finishing. Well, to tell you the truth I did not think of rumbling, but my foreman had spotted that they would rumble and they did. He just puts them in a portable die and sets it going, and leaves them for a time and they come out already trimmed.

On the question of lugs and so forth, broken off mouldings, it is not worth doing that. Rumbling is really an expensive form of moulding. In one company I worked for we had a reclaiming man who reclaimed moulds for me and stuck bits on and rivetted them up and so forth, but he did not earn his money. He certainly did not earn anything for the company. If you have got a very expensive moulding and you want to stick a bit on you can do it by welding. You do it mainly with a particular material which the powder manufacturers will supply you with, but it is such a terrible process it is cheaper to make a new one.

MR. KIRCHNER: I was rather interested when Mr. Chaffey mentioned that it was possible to obtain an accuracy of plus or minus .002 in. to the inch on mouldings and it rather seems to me that if this can be accomplished, and seeing that the moulds are rather expensive items, it would be a point of interest to know how long a mould retains such accuracy. I should think the wear on a mould would be rather rapid, particularly around the area where the flash occurs. I believe quite a lot of moulds are chromium plated, and I would rather like to know whether Mr. Chaffey thinks there are any particular advantages in chromium plating moulds, and if so what they are? Regarding hobbing, I think it is a point that if you hob the steel it is necessary to polish the top surface of the blank, and that that polished surface is the surface which you finally obtain inside the moulding. Referring again to the question of accuracy is there any difference in the accuracy obtainable between thermo setting or cellulose materials, as used for injection moulding. Is it possible to obtain a greater accuracy per inch, that is more than

.002 in. per inch ? In the case of injection moulding, Mr. Chaffey mentioned that curing time was important, that is to say a moulding should not be under-cured or over-cured. It seems to me that with portable moulds, owing to the fact that the moulds are taken out of the press, and that their temperature when they are put back into the press is rather doubtful, it is probably more difficult to control the real curing time on a portable mould as compared with an automatic mould which remains in the press and is maintained at a constant temperature. There was one point that I was rather surprised Mr. Chaffey did not mention, and that was fixtures into which mouldings, I believe, are sometimes inserted after they are taken from the mould whilst they are cooling, to prevent distortion. I would like to know if such fixtures possess any particular advantages. The last point is semi-humorous. Do you really think, Mr. Chaffey, that the fact that moulding steel should be 9d. to 1s. a pound is very important when you consider that the cost of the material in a mould is a very small proportion of the total cost ? My point, I tnink, is that it is worth while putting a Rolls Royce on good tyres.

MR. CHAFFEY : With regard to the accuracy per inch and the wear of the mould—the first item that comes in there is what the mould is made of, and what material you are moulding. Obviously if you are using a material with a mineral filler the wear or abrasion of the material on the mould is higher than if you are using a wood filler. Customers often say to me, " If I lay down a moulding tool how long will it last ? " and I presume that is really what you are trying to get me to commit myself to. I have not yet committed myself, and all I can say is that it may make 50,000 or 100,000 parts. That is just about how much we know about it. Nobody knows the wear or abrasion of steels, and I should imagine it would be very difficult to obtain.

Chromium plating is obviously the best for wear. It also reduces the sticking troubles that are sometimes experienced, such as bakelite sticking, or the moulding material sticking to the actual die. But we have learnt a lot more about this sticking business than we knew some years ago. It is mainly due to oxidisation of the steel, and the material adhering to the film of oxide on the actual mould. We take steps to cure that before we start to mould as far as we possibly can. Chromium plating is not the cure for all these troubles. We have had moulds stick with chromium plating and scratched our heads and not known why. The advantage of chromium plating is obviously the finish, but with chromium plating you have got to choose a place where you can do it, and in this connection it is no use chromium plating on a base of copper. I always put forward this theory, and that is that if you have a layer of copper underneath the chromium, the chromium is hard and the copper is

soft, and you can imagine that you would get a terrific pressure, local pressure, on any part of your mould with chromium, and the chromium cracks because the copper does not support it. You must bear in mind that chromium is very, very difficult to work, and that is one of the disadvantages of using it. Do not have it done on a copper base. Have it done direct on the the steel and polish by hobbing. I have seen winding marks on a blank which was cut out almost $^1/_{16}$ in. wide when you stretched it in the actual impression. At one time when we were trying hobbing we polished the blanks so that I think if you etched them you would get no tramlines or anything, just the straight structure of the steel.

On the question of curing on portables, this is not as accurate as if it were done in the press. Mr. Halliwell, I think, said he could see no need for the portable mould. The portable, to be frank, is often the forerunner of the automatic mould. The customer does not know what his requirements are going to be. He says, "I only want 50. I will have a portable mould for about 2,000 moulds alone." You have to try your articles out and portables are really the most useful methods of doing it.

With regard to the question of fixtures, I have to be careful what I say to-night on that subject. I am in trouble with a job in the shop at the present moment in which we had not counted on any excessive distortion because we thought we had planned the ejection beautifully. We were ejecting on every point that was necessary, but we were still getting distortion, and we are having to flatten to make sure that the article retains its shape on cooling. It has got gaps on the side of it and it tends to curve. Also you have to be careful that with a large flat moulding you cool both sides equally. Otherwise obviously you get a curve.

On the question of mould steel—well, I do not know that it is not so important a question. Imagine an ordinary simple rose bowl. After all, it is moulding. The labour involved in turning it, just a plain dial of 10 in. in diameter, turning on top, is going to be something like £15. Why, your steel would cost you £10. So why not go for cheaper steel if you can get it ?

I am thinking chiefly of the expense of the steel. After all, you have to carry stocks. You must consider the capital expenditure to meet the demands—I am talking now from a true moulder's point of view—to meet the demands of every customer who comes. You have to keep a tremendous stock of die steel in. You need a tremendous stock. You have got a range from something like 1 in. diameter up to 8 in. diameter, and so forth, and from 10 by 2 to 12 by 2, and in order to meet anything that may come along your capital expenditure would amount to £2,000 of steel for quite a small business. That has to be considered when dealing

with stocks at any rate, and if you can get it cheaper, why not?

A VISITOR: Could Mr. Chaffey give us any information on the draught or power that is required for a free drawing on mouldings?

MR. CHAFFEY: Yes, I like to get as high as I can. Actually we can have about 10,000 to the inch, that is 5,000 each side if possible, but the polish has got to be good and the tool maker has got to be right on top of his job. But there is the question of draw, the business of making little undercuts near your ejector and so forth. Well, as I explained to you when I started, when the mould open each side of the moulding goes lie that—I can't put it into words; I can only show you—it is then that often the mould takes the form of what we call a chimney, and so we use the method of undercuts—in fact we are using it to-day. In one job on the valve bases on the ejector that I showed you there is an undercut at the top of this to help the flow. We do not have the undercut at the bottom of the punch, but we have it at the top.

A MEMBER: I wonder if Mr. Chaffey could give us any information on the non-tracking qualities of the various components? Some people here of course—that is, in the electrical trade—know what I mean by non-tracking, and there is a good deal of discussion on this point. There is no doubt that in the electrical trade there is to-day quite a lot of controversy about the use of bakelite in electrical work. For the switch gear, although it is only 250 volts, they ininvariably use porcelain bases which have to be covered by bakelite. It looks bad I think, even to-day to see this, but for small switches the greater accuracy compared with porcelain bases makes it more useful from every point of view, but the fact remains that they use porcelain for switches and I would like Mr. Chaffey to give us some information on what he considers the best.

MR. CHAFFEY: This is really out of my element. It is not manufacturing methods. The last paper was supposed to deal with those questions quite effectively, but I know something of tracking material. Put it that way. There is no non-tracking mould material except in steatite. We have all got to face up to that fact, and it is just the same as the question of the shock proof—how high is high? But at the present moment the moulding material manufacturers are working on a material which they feel will be non-tracking. At the Government's request, I think. It is a very important point. Urea formaldehydes are better for non-tracking qualities. That is one of the difficulties, and if you have got a job which involves any tracking or flash or anything like that you have to be very careful.

MR. BEADLE: I must say that our experience has shown that it

is not a question of designing the article but overcoming the tracking.

MR. CHAFFEY : I had a cut at it one day with regard to the hand loom and I had to go round all sorts of corners, and our main trouble was whether we should have a back-fire. You no doubt have had more experience than I have. I do not know very much except what happened on that occasion. You know what you try to do for yourself, which is really putting the boot on the other foot.

MR. MOOR : With regard to moulding powders, particularly white powders, we have had a lot of trouble through the moulds staining the powders and not getting a nice white. The only way we have got over it is to use a steel which contains chromium. Is there any way of getting over that trouble than this ?

MR. CHAFFEY : You mean other than by using chromium plating ? Well, you have to have chromium plating done up several times, because it has worn in a year's time after a certain number of mouldings have been done. But I have heard of firms which submit that you must use stainless steel. I take it you mean chromium plating—chromium hardening ?

MR MOOR : It is chromium plating. We have never been able so far to get it done successfully. We cannot get in the corners, and if you have got the name of a firm which can go into corners I should very much like to have it.

MR CHAFFEY : As a matter of fact there was a process a man worked in London on this chromium hardening, and I think he was the originator of the steel chromium. His process was adopted by some well-known printers for their printing mills for cooling, carrying the printing and so forth, and of course, they are very important and they expect their dies to work to a specification. In other words you get a good job.

MR. PUCKEY : I was rather surprised that nobody has yet brought forward the question of the number of cavities per mould. Mr. Chaffey, I think, dispenses with it in rather an airy fashion, but at the same time I think it is one of the points that should have a little more attention than it has. I remember reading in an American magazine on plastics a couple of years ago an article on this particular subject and the writer developed a formula which at first sight appeared like a very difficult pianoforte composition, really seemed much too long and complicated for the ordinary man to work out. In fact the customer would probably be using the mould before you got the answer. I was discussing the problem a short time ago with an American friend, and he had developed a formula which is quite a simple one, and put it into graph form for working out the most economical number of cavities in any given mould. I have worked the formula out for quite a number of jobs and I believe we are proceeding on the right lines by a rule of

thumb method, but a formula should help. I do feel that is a thing that we should pay a little more attention to. It can be determined in a reasonably mathematical manner, and the fact remains that we can get a better method to-day than the more elementary rule of thumb methods used at the present time.

Mr. Chaffey also mentioned the question of presses where each press has its own pump instead of the central accumulator system, and said that of course the ordinary shops could not afford to use these. I presume he means the trade moulding shops could not afford to use them. Well, that seems to me to raise a very big point, because I am associated with a company which has a consumer moulding shop as one of its sections, and we work on the principle of spending more rather than less money on equipment and moulds. In fact we spend sometimes a darned sight too much I think, but nevertheless we do tend to go to the extreme of spending more rather than less money on it, and my own experience is that we are justified in doing that. I have one actual example where we have one very difficult job and a fairly elaborate die for moulding it. A customer quoted us for producing that job in a trade moulding shop. We found, however, that we could produce them much cheaper than an outsider, including high overheads. Of course Mr. Chaffey might say, "how high is high?" I would like to say that that machinery cost us a pretty substantial sum and one which I think would be much higher than that used by the moulding shop which quoted us. The man who quoted came and saw the new equipment that we had put in and his eyes nearly shot out when he saw it and he said, "Well, I could knock up something to equal that job for about £200 or £300." Well, our equipment cost us very considerably more than that figure. If there is a moral I suppose it is that with all our high overhead costs we were able to turn that job out very much cheaper with the expensive equipment than the large trade moulding shop with the £200 or £300. I suppose there is a moral somewhere, but I will leave it to Mr. Chaffey to try and find it.

An occurrence out of the general routine took place in our shop last week, when we had an accident with a girl who lost her thumb in a moulding press, and it has raised the point as to whether moulding machines should be taken as dangerous weapons in that sense of the word. We have all been accustomed to safety in the shops in connection with power presses, but this has rather opened our eyes to the plastic moulding presses being considered as dangerous weapons. I am just mentioning that point because it seems to me it is one of the things that is not realised perhaps as fully as might be.

There is one other comment and that is in connection with Mr. Chaffey's point, which I think was a very good one, about working the presses to the fullest possible capacity. I agree with him very

fully there, because after all the press is the essential thing. Your labour cost is very small in proportion to the equipment cost; but at the same time you have the fact that you may have five or six minutes curing time, in which the operator is presumably doing nothing. Well, of course it is not a crime to do nothing, but at the same time in this efficient world we do like to make use of these odd minutes, and it does seem to me a very great advantage if you can utilise the operator's time in doing some drilling or fettling or something like that on the mouldings when he has just produced them; in other words you do not want to do one operation in one part of the shop and another in another part of the shop, you want to reduce the amount on your work-in-process as much as possible. If you can turn out jobs from the press finished so that they go through the inspection department into the stores there is some advantage in this procedure.

We are making special arrangements whereby a drilling machine and a polishing wheel can be put into position adjacent to any press so that the man in his spare moments can finish the parts as they are taken from the mould, and I see no reason why we should not take Mr. Chaffey's point of view of using the press as much as we can, and also using the operator as much as possible. If you can combine these two factors you are getting towards the ideal.

MR. CHAFFEY: Mr. Puckey has given me rather a lot to get on with, but on the questions of the number of impressions, if he has any formula with regard to the working made out I would like to see it, because I suppose out of my week's work I must spend 50% of my time having a shot at it, in other words finding out how many impressions to use on the contract. I have tried to work it out mathematically and have in fact gone into calculus, and I thought, "Well, it had better go to Cambridge and not remain at Sidcup." It was obviously of particular importance in working out the number of impressions for the contract. You must bear in mind both with regard to this point on the number of impressions and the question of plant that the consumer moulder's point of view is totally different from that of the trade moulder's point of view. A consumer moulder lays down to do a programme on which he is fairly definite. He knows what he is going to do. The trade moulder does not know what his first contract is going to be, but a consumer moulder says, "Yes, I am going to make 10,000 now and in six months time I am going to make another 10,000, and I am doubling that next year." That is his job and he lays a plant down for it. If he loses money on that plant he turns round and lays off on the Sales Department. The trade moulder cannot. He is only told, well, you have got contracts to cover—you have so many and nothing more. That is the different point of view which I want to bring home with regard to the number of impressions that you put in a tool and the plant that

you lay down. It is the chief difference between the two methods. The trade moulder says, "I am going to lay down plant for so many, for which I have an order." But beyond that he cannot say much more. You can lay down for 80,000 this year, and the next year it will be 100,000. I have got customers to do that, but I may be particularly lucky in this matter. My experience has been that if I can sell 300 I may sell 5,000 and get the tool accordingly. That is the general problem.

On the question of plant, again it is a question of capital involved. Do not forget the moulding industry has started with very little capital. Beyond ourselves nobody takes much interest in it. I started work at an aerodrome picking up bits of aeroplanes to make pins out of. Well, that was the beginning of the moulding industry in this country, and the trade moulders have gone a long way on these lines that they have got as much as they can for their money. When a man puts down £10,000 he counts not on getting in as many presses as he can but on the volume of business. He is not particularly interested in saying "I am going to have a machine laid down which is going to produce a job right, come what may." That is the attitude of the consumer moulder and rightly so. He is laying it down just as he would a press, but actually the trade moulder lays down the plant to do any job that comes along as far as he can see.

On the question of safety, I agree with you there. It is an important problem that is coming before the industry now, and it is a point to which great attention should be paid. Frankly, I cannot see in what way any safety devices can be incorporated on a press without detracting from its satisfactory working. Whether anything will be done about it I do not know. I have not seen any efficiently guarded hydraulic press yet. If they are going to safeguard the hydraulic press it will have to go beyond the bakelite moulding.

On the questions of operations on the press, this brings out the difference between trade moulding and consumer moulding. There is the fact that we have got a battery of presses and we have got to make them produce as much as we possibly can on a number of varied lines. I should think the majority of our jobs are not in a press. I visualise on our great production jobs one of these days having a sort of hand to hand system in the press, on to the drill and the drawing and buffing and so forth, but on the question of this beaker I do want to bring home to you one point there. Only this week my foreman said to me, "Look at that girl making those beakers. I don't know how she does it, but she is doing 1,200 an hour." Well, I very much doubt whether it would be wise to interfere with the press one little bit for the production of those beakers. The press operates and produces about 150 an hour, and my finishing girls know how to

do their jobs efficiently, and they understand how to cut their fingers and not to. I do not know many mechanical operations where you can go above that figure of 1,200. I have got another girl on the drilling of such things as valve bases. She has been doing it for years. She is doing the riveting over the valve legs which are stuck up inside the valve base. She is riveting these by means of a drilling machine with a drill moving backwards, and I have seen nothing to better it on time in view of the fact that she is doing 700 of these bases an hour. That is 4,900 holes an hour. That is not fiction. It is fact. And that is what I am bringing home to you. You will never get such figures and efficiency if you do it on the presses.

MR. BAMFORD: Mr. Halliwell mentioned a little earlier in the evening that this has been one of the most interesting lectures we have had. I am in complete agreement with that statement, but I do not know which has been the most interesting, the lecture or the discussion. Whether they be members of this Institution or members of the Institute of the Plastic Industries, or even non-members of those Institutions, I am convinced that every man in this room to-night will have received food for thought and will certainly be going away a much wiser man than he came. Personally I have been staggered by the facts which have emerged in the discussion, and particularly by the high production figures that our lecturer has just quoted regarding the finishing processes. There was one of the plastic products which intrigued me immensely. I did not have the courage to get up and ask a question about it ; I had hoped someone else would. It was the lady's hair slide—our lecturer said the Americans referred to it as a " Ben Hur "—which was depicted on one of the lantern slides. I would be interested to know how the bend was produced in that product after the moulding operation. We have had a long and interesting discussion and it gives me great pleasure to propose a vote of thanks to Mr. Chaffey for his lecture.

THE SCOPE AND POSSIBILITIES OF PLASTIC MATERIALS.

Paper presented to the Institution, London Section, by George Dring, M.A., B.Sc., F.I.C.

YOUR programme gives my lecture this evening the all-embracing title "The Scope and Possibilities of Plastic Materials." It may be assumed from this title—which I did not choose myself—that it is becoming increasingly evident how wide is the scope and how far-reaching the possibilities of plastic materials. With such an extensive field to cover it is inevitable that I shall have to omit almost all detail, however important, and I shall have to be satisfied if the bare skeleton of information which I am able to give serves as the basis of an active discussion and for further personal investigation of the scope and possibilities of plastic materials.

The subject of plastics has now a very extensive literature of its own, and several excellent periodicals in this and other countries are devoted entirely to the questions of their manufacture and use. At the end of this paper I have given a selected list of books and journals for anyone who wishes to go more fully into the matter.

There is an active trade organisation, The British Plastics Federation, and, on the technical side, there has been formed a special Plastics Group of the Society of Chemical Industry. There is also the Institute of the Plastics Industry which is composed of all persons interested directly or indirectly in plastics. Special courses in Plastics Technology are held in London, Birmingham, and Manchester, and examinations are held under the City and Guilds of London Institute.

I shall purposely avoid the use of trade names which are liable to be a little confusing, especially as one trade name can cover a whole range of different materials of quite different chemical nature. It is much simpler to divide the materials into their chemical classification as is shown in Table 1. In any case, I could not refer to all the trade names of the large number of plastics which are available on the market, and it would be unfair to select a few proprietary names and to omit others. The list of trade names

January 7, 1938.

given in the British Plastics Year Book provides a guide to the types of material covered by various trade names together with the names of the various manufacturers.

THERMOPLASTIC GROUP

(A) Natural Resins.
  (1) Animal—shellac
  (2) Vegetable (dammar gum : rosin)
  (3) Mineral—bitumen

(B) Cellulose Plastics.
  (1) Cellulose nitrate
  (2) Cellulose acetate
  (3) Ethyl cellulose
  (4) Benzyl cellulose

(C) Acetylene Derivatives.
  (1) Vinyl
  (2) Styrol
  (3) Methyl methacrylate

(D) Casein (not a true thermoplastic)

THERMO-HARDENING GROUP

(A) Phenol-formaldehyde

(B) Urea-formaldehyde

(C) Alkyd

OTHER RESINS NOT MENTIONED IN THIS PAPER

(A) Rubber Group.
  (1) Rubber
  (2) Synthetic rubber
  (3) Rubber derivatives

(B) Cumarone and indene resins

(C) Aniline resins.

(D) Aldehyde resins

(E) Ketone resins

(F) Numerous other resins
  (1) Organic
  (2) Inorganic

TABLE 1.

Plastic Materials.

I am not going to attempt to deal with all the plastic materials which can be made, but I have shown in Table I a list of plastic materials most of which have at least reached the manufacturing stage, although not all of them have as yet established themselves industrially. Research is going on continuously in an endeavour to find new combinations of chemicals to give new plastic materials. Many of these new plastics which are described in the chemical journals or in the patent literature, may never be heard of again, but there is always a possibility that some new plastic material with some new combination of properties will achieve a firm position in industry. One of the most important new arrivals into the sphere of industrial manufacture is methyl methacrylate, which is made by a series of chemical reactions which look, on paper, as though they should never have got out of the laboratory—a typical example of the laboratory product of one generation becoming the industrial product of the next.

The question is bound to be asked as to what is meant by that word " plastics " ? The word has now become firmly attached not only to the plastic materials used to manufacture the articles but to the manufactured article itself. Although the manufactured article is obviously not plastic, it is called a plastic article because it is made from a plastic material. The plastic article is shaped from a plastic material by the application of heat or pressure or both, and having been formed to that shape it retains that shape. The boundaries of the plastics industry cannot be rigidly determined by means of a definition, but it is now generally understood that the industry covers those materials which I have given in the table.

The two big general classes into which plastic materials are divided are the thermo-plastic and the thermo-hardening. A thermo-plastic material produces articles which are still thermo-plastic and can be softened again by heating. In other words, these thermo-plastic materials undergo little or no chemical change at ordinary moulding temperatures and can be repeatedly heated and cooled again without any marked alteration in their physical properties as measured at any given temperature. On the other hand, a thermo-hardening material produces articles which do not soften perceptibly when re-heated. The action of heat on a thermo-hardening material causes a chemical change to take place, and the moulded article once hardened cannot be softened again. The moulding process is irreversible. Thermo-plastic materials have the advantage from the manufacturers point of view that any scrap can be reworked over and over again. It is for the user, however, to decide whether it is desirable that any given article should or should not soften under heat and the desirability of using a thermo-

plastic or a thermo-hardening material is one of the first questions to be decided when considering the manufacture of any given article. It seems impossible that there can ever be found an organic synthetic material which shall have a high softening temperature comparable with an inorganic material, such as glass, but there is no doubt that a thermo-plastic material with a softening temperature well above the boiling point of water, say, at around 150°C. or higher if possible, would be very valuable, and there is no reason to suppose that such a material will not yet be found.

I shall now give a very brief description of the composition and methods of manufacture of the plastics I have mentioned in Table I, together with some indication of their uses and, to a certain extent, of their properties in relation to one another.

Shellac.

The first on my list is Shellac. As befits a natural product its use goes far back into history. It is the product of a tiny insect, the lac insect, which lives on certain trees in India. The insect lives on the sap of the trees and exudes the resin-like material which is collected by natives and sold for the production of shellac. Thousands of insects produce only grams of resin, yet the annual production is in thousands of tons. Shellac is the product made by refining the natural lac and is obtained in thin flakes by pouring the refined and molten lac on rotating cooling drums or by stretching by hand.

Shellac is characterised by a tenacity and resiliency which is peculiar to itself and which is not equalled by any of the synthetic resins. Many synthetic resins have been made approaching it in quality, but in those fields which it has made its own it can still challenge any newcomer. The one big use of shellac in the plastics industry is in the manufacture of gramophone records.

Bitumen.

This natural product is found in immense deposits in the Rocky Mountains region of America. It is an asphalt-like substance of high chemical purity and is evidently a deposit which has oozed out from the interior of the earth in a solution form and on exposure to air the solvent has evaporated leaving this hard wax-like substance.

One large use for pure bitumen is in the production of battery boxes which have to be quite non-absorbent and must resist the action of acids. Bitumen is a useful basis for plastics of the non-heat-hardening type and when incorporated with fillers, such as asbestos, cotton flock, and slate dust, forms the basis of many mouldings used in the electrical industry as insulators. Bitumen is the basis of so-called cold mouldings which are pressed to shape

in cold moulds and then hardened by slow stoving. In earlier days, this type of plastic was the only one available for the making of moulded parts. The finish is generally inferior to mouldings made from the newer synthetic resins but, in spite of this, there is still an extensive field of use for this class of plastics, especially where large mouldings are required and where low cost rather than quality is the determining factor. There is a large variety of compositions, the cost of which varies considerably, but an average cost may be taken as about 1½d. per lb., which is, of course, very attractive for certain classes of work.

Cellulose Nitrate.

The commercial production of cellulose nitrate goes back about seventy years and can claim to be the forerunner of the present day plastics industry. It is made by the action of a mixture of sulphuric and nitric acids on cellulose, which is thereby converted into nitrocellulose. The extent of nitration of cellulose can be controlled by regulating the strength of the sulphuric acid—nitric acid mixture. Highly nitrated cellulose containing 14% of nitrogen, and corresponding to the hexa nitrate, is highly explosive and is used as the explosive gun cotton. For use in the plastics industry the nitrogen content is controlled at around 11%. This nitrocellulose is soluble in a mixture of alcohol and ether but the film left when the solvents are allowed to evaporate is rather brittle and useless as a plastic. The incorporation of camphor with nitrocellulose, however, gives a valuable plastic material familar as celluloid. The camphor acts as a solid solvent dissolving the nitrocellulose fibres and converting them to a solid solution.

One serious objection to celluloid is that it is inflammable but in spite of that, it still represents one of the largest productions in the plastics industry to-day. It is produced in the form of rod, sheets, tubes, and other blanks which are sold to other manufacturers for fabrication but by far the largest quantity is used by the celluloid manufacturers themselves for the production of the many familar articles—combs, hairbrushes, toothbrushes, mirrors, and many other toilet articles as well as such goods as hollow toys.

Cellulose Acetate.

Nitrocellulose is inflammable; cellulose acetate is not. Cellulose acetate can be used for a number of purposes for which nitrocellulose is used but it also has many special uses of its own which are of particular interest to the plastics industry. Cellulose acetate is manufactured from cotton linters by treatment with glacial acetic acid, acetic anhydride, and a catalyst, usually sulphuric acid, under controlled conditions. The primary product is cellulose triacetate which is soluble only in rather inconvenient and expensive

solvents. The triacetate is, therefore, given what is called a ripening treatment, during which it is partly saponified. The cellulose acetate is then precipitated with water, washed, stabilised by washing with very dilute mineral acid, and dried. It is then soluble in acetone and is worked up into a dough with acetone and one or more plasticisers. Whereas camphor is generally used with nitrocellulose the most common plasticisers used with cellulose acetate are triacetin, the aryl phosphates, the alkyl phthalates, and various sulphonamides.

Like nitro-cellulose, cellulose acetate is produced in the form of sheets, rods, and tubes, but its greatest interest in the plastics industry is as a moulding. It absorbs more water than nitrocellulose and is not so tough and strong but it is very much less inflammable and can be worked in hot moulds with no more risk of fire than shellac or bitumen compounds. It is admirably adapted for the process of injection moulding in which the moulding material is heated until it is plastic and is then forced under high pressure through a small aperture into a cold mould which it fills completely and can be ejected immediately. This method of moulding gives a very high rate of output. This fact, and the possibility of reworking all scrap, are two of the outstanding advantages of injection moulding materials of this type.

Benzyl and Ethyl Cellulose.

The following summary is quoted from Rowell's "Technology of Plastics": "Chemically, these products are ethers, where as the acetate and nitrate are esters or equivalent to inorganic salts. They are not made directly from cellulose but the cotton or other cellulose is first made into an alkali cellulose with caustic soda and this is treated for some time with excess of benzyl or ethyl chloride. The excess reagent is recovered as much as possible, the mass well washed with water and then purified by solution in alcohol or other suitable solvent and reprecipitated by water.

"Only the benzyl cellulose has become a commercial product in Britain and it is sold as a moulding powder, compounded in much the same way as cellulose acetate, for pressure and extrusion moulding.

"Its water absorption is decidedly less than the usual acetate composition and it is, therefore, not so easily stained by ink when moulded to form a fountain pen barrel. Its resistance to chemical reagents is also greater; it is more stable than the acetate and its softening point is a little higher. The cost of manufacture is obviously more than the nitrate or acetate but with larger output it may become a serious competitor for several uses."

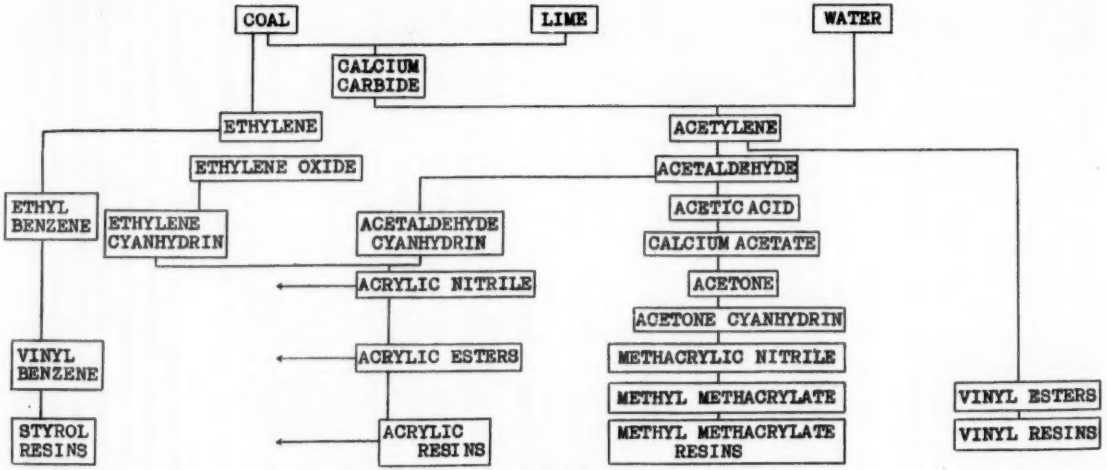
COAL
LIME
WATER
CALCIUM CARBIDE
ETHYLENE
ACETYLENE
ETHYLENE OXIDE
ACETALDEHYDE
ETHYL BENZENE
ETHYLENE CYANHYDRIN
ACETALDEHYDE CYANHYDRIN
ACETIC ACID
CALCIUM ACETATE
ACRYLIC NITRILE
ACETONE
ACETONE CYANHYDRIN
VINYL BENZENE
ACRYLIC ESTERS
METHACRYLIC NITRILE
METHYL METHACRYLATE
VINYL ESTERS
STYROL RESINS
ACRYLIC RESINS
METHYL METHACRYLATE RESINS
VINYL RESINS

TABLE 2

Acetylene Derivatives.

In the third group of my general table of thermo-plastic materials I have classed together a group which I have called acetylene derivatives. Their chemical relationships and their derivation from the three primary substances, coal, lime, and water, is shown in Table 2. This Table, as also Table 3, in a somewhat altered form is based on the composite table " A Scheme of Plastics " given in " Kunststoff Wegweiser 1937," the Handbook published in connection with the exhibition Acheme VIII held at Frankfurt-am-Main last year.

Styrol resin, or more correctly Styrene resin, is a polymerised phenyl ethylene, or, stated another way, vinyl benzene, and has much in common with simple aliphatic unsaturated hydrocarbons such as butadiene and methyl butadiene, the monomer of one of the most important synthetic rubbers. The acrylic resin monomers on the other hand are esters ; methyl methacrylate is an ester of an unsaturated acid ; the vinyl compounds are esters of an unsaturated alcohol.

I do not propose to describe at length the preparation of any of these particular resins as the essential information is shown in Table 2. The styrol resins are well known by reason of their electrical properties which are unequalled by any other resin. The vinyl resins are not yet well known in this country but methyl methacylate resin, which is manufactured in this country, has become of increasing interest in the past year or two as an organic glass of outstanding properties. It is tough and elastic and can be pressed to shape by heating. It has less expansion and contraction than glass and greater transparency and strength. It has a higher water absorption than glass and is softer and scratches more easily but nevertheless its other properties are such that it is already being extensively used in aeroplanes. It is also being used in motor cars and an exceptionally interesting development is in the moulding of optical lenses for cameras, telescopes, and opera glasses.

Casein.

Casein plastic is derived from milk, about 3¼ gallons of skim milk being required to produce 1 lb. of casein. The casein is precipitated from the milk by rennet, separated, washed, filtered, and dried. In Table 1 I have shown casein as a thermo-plastic but this is not strictly true. The precipitated casein dough is moulded by extrusion or pressure into sheets, rods, tubes, and other shapes and the moulded shapes are then hardened by soaking in formaldehyde solution. The hardened material can be moulded as a thermo-plastic but the stock sheet, rod, and tube are usually machined to final shape.

Casein plastic has a definite moisture content which must be maintained within certain limits. If it is dried free from moisture

it not only shrinks but becomes brittle and practically useless while if it is kept wet it swells and eventually decomposes. Nevertheless it is widely used for machined goods in a similar manner to celluloid.

Thermo-Hardening Resins: Phenol-Formaldehyde Resin.

I now come to the second group on my list of plastic materials—the thermo-hardening or thermo-setting resins. The two chief members of this group are the phenol-formaldehyde resins and the urea-formaldehyde resins. Their derivation from the three primary substances coal, air, and water, is shown in Table 3.

I propose to deal a little more fully with phenol-formaldehyde materials than I have done with the other plastics I have mentioned. They are the materials in which I myself am chiefly interested and I have been asked to deal with them in a little more detail but, at the same time, I cannot do more than just touch on some of the chief points of interest. I do not want to give you a false perspective of the plastics industry. I am singling out the phenolic group for special mention because of my own interest in them and because of the wide general interest which they have as moulding materials but other experts, working on any of the various plastic materials, could give a full length lecture—or more probably several lectures— on each of the different plastics I have mentioned.

The main raw materials for the manufacture of phenolic resins are phenols and formaldehyde. The generic term "phenol" covers the various homologues of phenol, such as cresols and xylenols, and other substituted phenols. It is true that the largest amount of phenolic resinoid materials are made from phenol and cresol but xylenols and other substituted phenols are used in considerable quantitites for special purposes, in particular for the production of oil-soluble resins which I shall mention later.

Phenol and cresol are produced from coal tar. The various tar acids are extracted by means of caustic soda and then precipitated with acids. The tar acids are then separated into very carefully controlled fractions to give the various classes of phenolic material used in the phenolic resinoid industry. Phenol can also be prepared synthetically from benzene by chlorination or sulphonation followed by hydrolysis with caustic soda.

Formaldehyde is produced by the oxidation of methyl alcohol. Methyl alcohol was formerly produced by the dry distillation of wood but is now made almost entirely synthetically from carbon dioxide and ammonia.

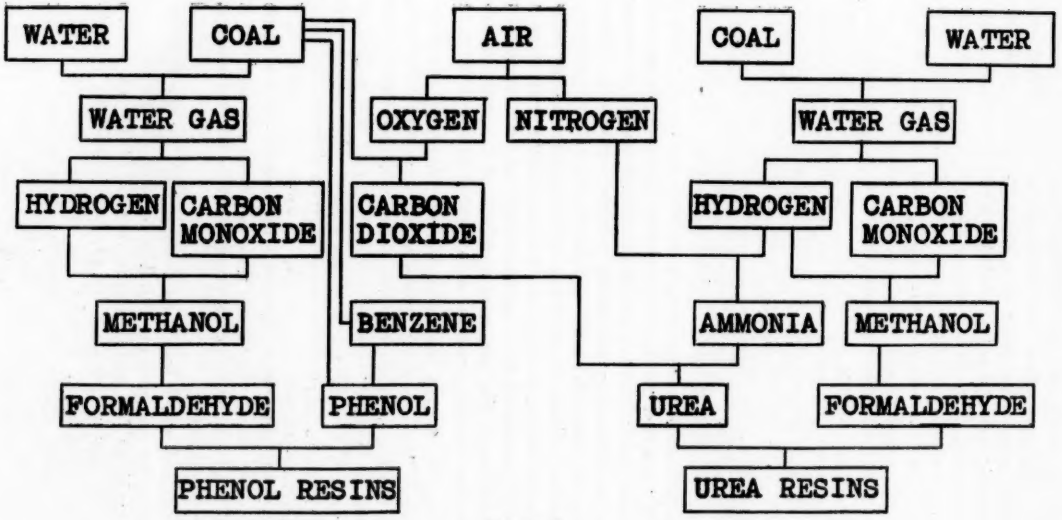
WATER
COAL
AIR
COAL
WATER
WATER GAS
OXYGEN
NITROGEN
WATER GAS
HYDROGEN
CARBON MONOXIDE
CARBON DIOXIDE
HYDROGEN
CARBON MONOXIDE
METHANOL
BENZENE
AMMONIA
METHANOL
FORMALDEHYDE
PHENOL
UREA
FORMALDEHYDE
PHENOL RESINS
UREA RESINS

TABLE 3

Phenol or cresol and formaldehyde are reacted together under very carefully controlled conditions, in a steam-heated still in the presence of a catalyst, the speed and type of the reaction and the type of resin produced being controlled by the amount and the kind of catalyst used. For all practical purposes there are two main types of phenolic resinoids produced, one made with alkali catalyst and the other made with acid catalyst. The usual commercial resins made with alkali catalyst are often called " one step resins " from the fact that continued heating converts them directly into the infusible insoluble stage, known as the " C " stage. Acid catalysed resins, as usually made, do not harden on the further application of heat but remain fusible and soluble until they are reacted under alkaline conditions with further quantities of formaldehyde thus giving the so-called " two step resins." The " two step resins " are generally used for the production of moulding powders while " one step resins" are generally used for the manufacture of laminated materials.

At the present time, moulding powders are generally manufactured by the dry process. In this process, the acid-catalysed resin is finely ground and then mixed with fillers and the other necessary ingredients of a satisfactory moulding powder—hexamine, plasticisers if necessary, mould lubricants and pigments or dyes to give the required colour. These various raw materials are all bulked together and then treated on hot rolls or in a Banbury mixer, when the filler becomes impregnated with the resin and the reaction is advanced to the desired stage. The material is taken off the rolls in sheet form, which is then cooled, cracked and ground to the desired mesh.

The stage to which the materials are taken on the rolls is very important. The moulding material, as supplied to the customer, must be in such a condition that, when put into the heated moulds and pressure applied, the moulding material will soften with heat and be pressed into all parts of the mould. The degree of advancement of the moulding powder must vary for different types of moulds and different shapes of mouldings. In some cases the moulding powder must flow easily, when the moulding material is said to be " soft"; and in other cases very little flow is necessary and the moulding material is advanced as far as possible while still retaining sufficient flow for moulding.

The method which has been standardised by the British Plastics Federation for determining the flow of phenolic moulding materials is the Cup Flow Test and this same method of test has been incorporated in the new specification for phenolic moulding materials which I shall mention later. Briefly, the method consists in moulding a cup or beaker, under very strictly standardised conditions, and measuring the time from the moment when the hydraulic pressure is applied to the instant that the flash ceases to move. Commercial

powders generally give a cup flow of from four seconds for very soft materials to thirty seconds for very stiff materials. There is no need to give full details of the test, as these have already appeared in British Plastics, July, 1934, and will appear in the British Standards Specification to be published shortly. The details of the mould are shown on the screen and are possibly familiar to many of you. The mould is standard in the matter of height, diameter, taper, bottom thickness, thermometer hole position, polished surface, flash type construction, and flash area.

The filler generally used in moulding materials is woodflour and gives moulding materials of good, general, average all-round properties suitable for the majority of applications. For special applications, however, other fillers may be preferred and a large number of varieties of moulding powders are available with different types of filler as well as with different types of resins. Ordinary moulded phenol-formaldehyde materials containing cellulose fillers should be satisfactory for use up to 120°C., and even up to 150°C. if this temperature is not continuous. They begin to blister at 160° to 170°C., but, by the use of asbestos and other inert mineral fillers, moulding materials can be made to have blister temperatures as high as 210°C. or, with a specially made mineral filled material, even 250°C. If short fibre asbestos is used, the finish is extremely good but the mouldings are rather fragile. Greater strength can be obtained with long fibre asbestos but the fibres usually show on the surface of the moulding and detract from the appearance of the moulded article. Mica, the use of which is patented, is used to give low power factor and high water resistance. Fabric materials of various kinds are used in the manufacture of materials with high impact strength and a whole range of materials is available giving various impact strengths. I do not propose to deal with all the range of materials which can be made with various fillers—it would take far more time than I have this evening ; and new materials are continually being made with new combinations of properties. It cannot be too strongly emphasised that each plastic material has its own unique—I would emphasise that word unique—combination of properties. Fabric fillers, which give greater strength, usually give lower water resistance and higher bulk factor ; mineral fillers, which give higher water resistance, usually give lower strengths unless in fibrous form and lower shrinkage in the mould.

The many uses of moulding powder cannot be summarised in a few words. Mouldings are used in practically every industry and a haphazard list would include such a diversity of articles as telephones, radio cabinets, meter cases, ashtrays, boxes and containers of all kinds, motor car window frames, distributors, binoculars, wall plates, knife handles, door handles, bottle caps, spinning buckets, fishing reels, and golf clubs.

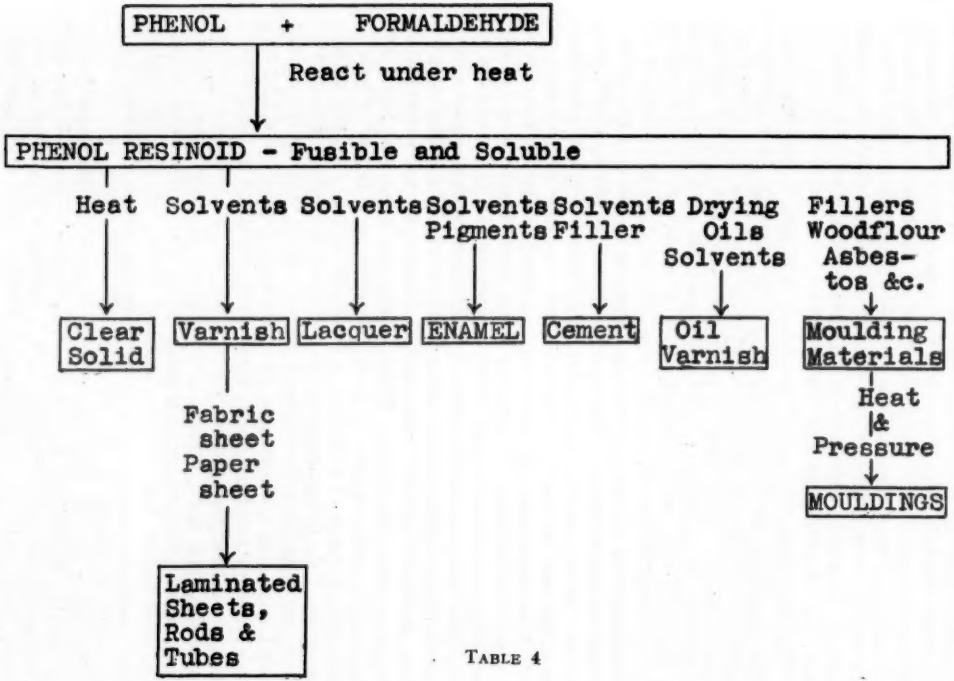
PHENOL + FORMALDEHYDE
React under heat
PHENOL RESINOID - Fusible and Soluble
Heat
Solvents
Solvents
Solvents
Pigments
Solvents
Filler
Drying Oils
Solvents
Fillers
Woodflour
Asbestos &c.
Clear Solid
Varnish
Lacquer
ENAMEL
Cement
Oil Varnish
Moulding Materials
Fabric sheet
Paper sheet
Heat & Pressure
MOULDINGS
Laminated Sheets, Rods & Tubes

TABLE 4

The second largest use of phenol-formaldehyde resins is in the manufacture of laminated products. Laminated materials are made by impregnating rolls of paper, fabric or asbestos sheet with a solution of resin in spirit and passing through a heated oven to drive off the solvent and polymerise the resin to the required degree. The dried, impregnated material is then cut up into sheets of the required size, which are stacked together and pressed between metal plates in large hydraulic presses at pressures of the order of one to two tons per square inch. In this way laminated boards are prepared up to 8 ft. × 4 ft. in size and from .005 in. to 5 in. or more in thickness. Many various qualities of laminated board are available for all kinds of electrical, mechanical and decorative uses. Thin veneers are made which are adhered on to plywood for table tops and panelling. If required, veneers can be pressed on to millboard core. Special requirements of very low water absorption or superior punching quality can be met. Laminated fabric materials are used in large quantities for silent gears and bearings.

Even though I have dealt more fully with phenol-formaldehyde resins than with any of the other resins I cannot give a full summary of the many ways in which it is used. Table 4 shows many of the main products, but is not complete.

One of the newer uses of phenol-formaldehyde resins which is attracting a great deal of attention is their use in oil varnishes, paints and enamels. The phenol-formaldehyde resins used for this purpose are derived from various substituted phenols and their use in conjunction with drying oils gives a resistance to chemical agents and to weathering which sets up an entirely new standard in the paint and varnish industry. Although the amounts of synthetic resins used in this country are below the very high figures which have already been reached in America, their use in this country is steadily increasing.

Urea-formaldehyde Resins.

There are a large number of points of correspondence between urea resins and phenolic resins and a large number of the general comments I have made in the case of phenolic resins can be, as you probably know, applied to urea resins. The one great advantage which urea resins have over phenolic reins is that they are far more light resistant and can give very light-coloured and light-fast moulding materials and laminated materials.

As is shown in Table 3, urea is made from ammonia and carbon dioxide. Thiourea, which is used to a much smaller extent, can either be made from imported cyanamide or from ammonium sulphocyanide obtained as a by-product of gas manufacture. In the manufacture of urea moulding powders either urea or a mixture

of urea and thiourea is allowed to condense with formaldehyde. A syrup is formed containing some 50% to 60% of resin and this syrup is used to impregnate woodflour or cellulose filler, the mass being then dried and so advanced to a stage suitable for moulding. The dried material is then ground and can be moulded in similar moulds and in a similar manner to the phenol-formaldehyde materials. The manufacture of moulding powders is the main use of urea resins at the present time, and the many decorative mouldings, tableware and picnic ware made from them must be familiar to every one.

Other uses of urea resins are as a filler for textiles to give anti-creasing fabrics, as a constituent of lacquer finishes and in the manufacture of laminated sheet.

Alkyd Resins.

I propose only to mention one type of alkyd resin this evening, that prepared from glycerine and phthalic anhydride. Glycerine is derived from animal fats and vegetable oils and is a by-product of the soap industry. Phthalic acid or phthalic anhydride is made from naphthalene, which is a by-product of the gas industry. The resin produced from glycerine and phthalic anhydride is a hard, water-white inert resin-like solid material which can be readily cast into shape and hardened by a prolonged period of heating. So far, this class of material has not been developed for the moulding industry on account of its slow rate of hardening. When finally hardened, however, it is reasonably colourless and cuts in a manner similar to horn. It can be readily machined and is used for decorative purposes, such as bangles, trinkets, pencil barrels, etc.

Comparative Properties of Plastic Materials.

I have now, all too briefly, and quite inadequately, given you an outline of the chief plastic materials which you are likely to encounter to-day in actual use in industry. As production engineers you are all doubtless most keenly interested in the properties of the various plastic materials which are available, but the industry is so relatively young and growing so rapidly that it is impossible to give you the kind of data which you look for in the relatively stabilised form which you know with regard to metals, and the materials of construction, which have been used by engineers for generations past. The plastics industry is working hard to give you this information, but I cannot point you to any single book or any single publication which gives all the information you require.

One attempt at a fairly comprehensive classification of the properties of plastic materials is given in chart form in the October issue of the American Journal " Modern Plastics," but, most likely, if you consulted this chart, you would not find just the information you wanted. At the head of this " Plastics Properties Chart " it

Properties	Phenol-formaldehyde moulding compounds			Urea formaldehyde compound Alpha cellulose filler	Vinylchloride acetate resins unfilled	Methyl methacrylate resin
	Woodflower filler	Mineral filler	Fabric filler			
Compression ratio	2.5–3.0	2.2–7.1	2.5–11.0	3.0	2.0	2.0
Specific gravity	1.34–1.52	1.70–2.09	1.37–1.40	1.48–1.50	1.34–1.36	1.18
Tensile strength in lbs. per sq. in.	6,000–11,000	5,000–10,000	6,500–8,000	8,000–13,000	8,000–10,000	7,000–9,000
Modulus of elasticity lbs. per sq. in. $\times 10^5$ ...	10–15	10–45	7–12	16	3.5–4.1	6
Compressive strength lbs. per sq. in.	16,000–36,000	18,000–36,000	20,000–32,000	24,000–35,000	—	8,000
Flexural strength in lbs. per sq. in.	8,000–15,000	8,000–20,000	10,000–13,000	13,000–15,000	10,000–13,000	15,000–17,000
Impact strength ft. lbs. ASTM, D 256–34 T. C = charpy. I = izod. N = notched. U = unnotched.	0.10–0.28 I,N	0.11–0.36 I,N	0.4–2.4 I,N	0.7–1.5 C,U	0.3–0.6 I,N	0.25–0.5 C,N
Softening point °F.	None	None	None	None	130–160	170–235
Breakdown voltage, 60 cycles, volts per mil. (instantaneous).	300–500	250–400	300–450	650–720	400–500	480
Power factor, 10^3 cycles	0.04–0.15	0.10–0.15	0.08–0.20	—	0.0143	—
Water absorption, immersion twenty-four hours, ASTM D 48-33.	0.2–0.6	0.01–0.3	1.0–1.3	1–2	0.05–0.15	0.3

TABLE 5.

	Styrene resin	Shellac compound	Casein	Cellulose acetate	Cellulose nitrate
Compression ratio	2.5	—	—	2–2.8	—
Specific gravity	1.05–1.07	1.1–2.7	1.35	1.27–1.63	1.35–1.60
Tensile strength in lbs. per sq. in.	5,500–7,500	900–2,000	7,600	3,500–10,000	5,000–10,000
Modulus of elasticity lbs. per sq. in. $\times 10^6$ ...	4.6–5.1	—	5.1–5.7	2–4	2–4
Compressive strength lbs. per sq. in.	13,000–13,500	—	—	11,000–16,000	—
Flexural strength in lbs. per sq. in.	6,500–8,000	—	—	5,200–8,800	—
Impact strength ft. lbs. ASTM, D 256–34 T. C = charpy. I = izod. N = notched. U = unnotched.	0.16–.025 I,N	—	1.0 I	3–12 C,N Per sq. in.	3–12 C,N Per sq. in.
Softening point °F.	110–200	150	200	145–260	160–195
Breakdown voltage, 60 cycles, volts per mil (instaneous).	500–700	100–400	400–700	800–850	600–1,200
Power factor, 10^6 cycles	<0.0001	—	—	—	—
Water absorption, immersion twenty-four hours, ASTM, D 48–33.	0.00	—	3–7	1.4–2.8	1.0–3.0

TABLE 5. (continued).

is stated: "The values for the properties in the accompanying chart are based upon maximum and minimum figures submitted by a number of manufacturers of each type of plastic material. Differences in test procedure and sizes of test specimens may lead to erroneous conclusions in some cases if direct comparisons are attempted. Special grades of material are often available which excel in one particular property. The manufacturers should always be consulted before making a choice of materials." That last sentence is sound advice. If you desire information in regard to any particular plastic, you should get in touch with the manufacturers and put your problem up to them. None of the reputable manufacturers of plastics would advise the use of their material if that material were unsuitable for the purpose. It is impossible for any but a specialist in plastic materials to keep in touch with all the varieties of new materials which are available. In many new applications, the conditions are likely to be quite different from the conditions met with in any previous application and the manufacturer will endeavour to produce a new modification with characteristics suitable for the application in mind. Service of this kind cannot be obtained by consulting a table of figures.

For my purpose this evening I have prepared a slide (Table 7) comparing certain properties of a few selected plastic materials. This table is a small abstract from the chart given in "Modern Plastics" to which I have just referred. I cannot deal with all the figures in this table, but there are just a few general points to which I would call your attention. In the first place, we have the compression ratio, which is more generally known in this country as the bulk factor, which varies from 2.0 to 3.0 in the case of unfilled and woodflour-filled materials. The mineral filled phenol-formaldehyde materials go up to 7.1, a figure which would indicate a filler of fibrous asbestos material, and in the case of fabric materials the figure is as high as 11. Fabric fillers can vary from ground cotton up to the well-known flaked fabric materials. Under specific gravity you will note considerably increased figures in the case of heavy mineral fillers. Mechanical properties are a combined function of the resin or binder and the filler and, as will be seen from the Table, quite a wide range of variation is possible by variation in either the filler or the binder. The softening point tells its own story. You will note the extremely low power factor of Styrene resins, to which I have already referred and its almost total lack of water absorption. The highest water absorption occurs in the case of casein which I have already mentioned in discussing that material.

To illustrate the point I made with regard to getting into touch with the manufacturer, I have had a few slides made of data sheets issued by my own firm with regard to some of the more widely used moulding materials. These slides are only intended to serve as

Classification of Rubber-free, Non-ceramic, Insulating Molding Materials

T.	Description	Mechanical props: Bending strength kg/cm²	Mechanical props: Impact cmkg/cm²	Mechanical props: Impact notched bar cmkg/cm²	Therm. props: Heat resist. °C.	Therm. props: Flame resist.	Elec. props: Surface resistivity after twenty-four hours in water Grade	Moulding technique
I_1	Phenol-formaldehyde resin, inorganic filler.	500	3.5	1.0	150	4	3	Hot moulding.
I_2		500	3.5	2.0				
M		700	15.0	15.0				
O	Phenol-formaldehyde with wood-flour filler.	600	5.0	2.0	100	2	3	Hot moulding.
S		700	6.0	1.5	125	3		
T_1	Phenol-formaldehyde with cotton fibre filler.	600	6.0	6.0	125	2	3	Hot moulding.
T_2		600	12.0	12.0				
T_3		800	25.0	—				
Z_1	Phenol-formaldehyde resin with paper pulp filler.	600	5.0	3.5	125	3	3	Hot moulding.
Z_2		800	8.0	5.5				
Z_3		1,200	15.0	10.0				
K	Urea-formaldehyde with organic filler.	600	5.0	1.2	100	3	4	Hot moulding
6	Natural resin synthetic or natural bitumen organic filler.	350	3.5	—	65	2	3	Hot moulding.
7		250	1.5	—		1		
8	Bitumen with inorganic filler.	150	1.0	—	45	3	4	Hot moulding.
A	Cellulose acetate with or without fillers.	300	15.0	—	40	1	3	Hot moulding.
2	Synthetic resin plus asbestos filler	350	2.0	—	150	4	3	Cold moulding.
3		200	1.7	—	150	4	3	
4	Natural or synthetic bitumen with asbestos filler.	150	1.2	—	150	4	3	Cold moulding.
Y	Lead borate with mica filler.	1,000	5.0	—	400	5	4	Hot moulding.
X	Cement or water glass with asbestos filler.	150	1.5	—	250	5	—	Cold moulding.

illustrations. Similar detailed information can be obtained from other manufacturers on their products.

Specifications for Plastics.

One of the first attempts to classify a whole range of plastic materials for a particular use was the classification brought out by the German V.D.E. This table, which was first published in 1922 has been added to and altered in various ways for the past fifteen years and the latest publication of this table from "Plastische Massen in Wissenschaft und Technik," November, 1937, is given in Table 6. Here are tabulated the minimum properties which must be reached by a whole range of different plastic materials (excluding rubber and ceramics) which may be used for electrical purposes. When the table was first published, only the type designation was given without any indication as to the chemical nature of the plastic. Any material which fitted the figures could be classed accordingly. Every specialist knows, however, that each plastic has its own particular combination of properties and in actual practice only one particular plastic can fit each type designation. Consequently the chemical composition has now been filled in—an aid in classification as well as specification which has greatly improved the value of the table. As time has passed new types have been added and old types have been sub-divided. Thus we have :—

Type 1_1—with granular inorganic fillers (e.g., powdered minerals).
,, 1_2—with fibrous inorganic fillers (e.g., asbestos fibre).
,, M—with inorganic yarns (e.g., asbestos string).
,, T_1—with short cotton fibre filler.
,, T_2—with cotton clippings.
,, T_3—with lengths of cloth.
,, Z_1—with short fibrous pulp (flock, paper flock).
,, Z_2—with cellulose cuttings (paper cuttings).
,, Z_3—with lengths of paper.

In considering the properties of moulded plastic materials it must be borne in mind that all the various tests of electrical, physical, and mechanical properties are made on test specimens which are moulded under fixed standard conditions and tested according to a standardised method of test. It is inevitable that different manufacturers and different users have developed and have used different standards for measuring the same property. Efforts are now being made to standardise these methods of test so that figures for one particular property for one particular type of plastic can be quoted on one basis. I shall refer directly to what is being done in England but before I leave the subject of German V.D.E. Specification I

would point out that the figures given in the German tables cannot be directly related to British figures or either set of figures to American figures. Whether all countries will internationally agree to one method of test and one set of figures I do not know. At the present time, although international co-operation has been mooted, I believe it to be outside the bounds of practical politics and each country must legislate for its own manufacturers.

In England, as in Germany, the initial enterprise in the standardisation of plastic materials came from the electrical industry and a large number of the standard methods of test have been developed by the Electrical Research Association. I do not propose to mention in any detail the work which is being done in America but standardisation work in that country is also being carried out under the control of an electrical committee of the A.S.T.M.

The present British Standards in England referring to plastic materials are :—

B.S.S. 316—Synthetic resin varnish-paper boards and tubes for general electrical purposes.

B.S.S. 474—Synthetic resins (phenol-aldehyde type) for the manufacture of boards, tubes, and cylinders.

B.S.S. 488—Moulded insulating materials suitable for accessories for general electric installations.

B.S.S. 514—Baking insulating varnish (bitumen type) for electrical purposes.

B.S.S.547—Synthetic-resin bonded-paper sheets (Grade I) for electrical purposes.

B.S.S. 668—Laminated synthetic-resin bonded sheet (fabric base) for use as gear material.

B.S.S.688—Bituminous filling compounds for electrical apparatus.

I do not propose to discuss these standards in detail. Several are under revision and it is also proposed to widen the scope of the electrical specifications by producing further specifications covering the use of plastic materials for other specific electrical purposes.

A somewhat different set of specifications is now under consideration in this country and the first of them is in the hands of the printers at the present time. This specification entitled " Synthetic Resin (Phenolic) Moulding Materials and Mouldings " gives the minimum properties which can be expected of that class of material. The phenolic moulding materials have been divided into five types :—

Type G—General type
,, GX—Improved general type

Clause No.	Test	Appendix	Type letter				
			G	GX	MS	HS	HR
10	Ultimate tensile strength (lbs. per sq. in.)	C	5,'00	7,000	6,000	6,000	3,500
11	Impact strength (ft. lbs.)	D	0.11	0.13	0.30	0.90	0.07
12	Water absorption (mg.)	E	200	120	300	350	100
13	Swelling after immersion in water (in.).	E	0.003	0.003	0.006	0.010	0.002
14	Plastic yield	F	5 mm. at 100°C.	5 mm. at 140°C.	5 mm. at 100°C.	5 mm. at 100°C.	5 mm. at 180°C.
15	Electric strength at 90°C. (volts/mil.)	G	20	60	20	20	20
16	Surface resistivity after immersion in water (megohms)	H	100	1,000	100	100	100
17	Resistance to crushing after heating (lbs.)	J	—	—	—	—	500

TABLE 7

PLASTICS INDUSTRY IN U.S.A. (PRODUCTION GIVEN IN 1,000 LB. UNITS)

PLASTIC	1934		1935		1936	
	Product'n	Price per lb.	Product'n	Price per lb.	Product'n	Price per lb.
		Cents		*Cents*		*Cents*
Cellulose acetate	4,660	—	10,732	50	13,265	40
Cellulose nitrate	12,360	—	19,387	—	20,540	—
Ethyl cellulose	—	—	—	150	—	85—115
Phenolics :						
Moulding	—	—	35,000	14	52,000	—
Laminated	—	—	10,000	—	17,000	—
Varnish	—	—	2,000	—	5,500	—
Cast	4,968	47.5—50	4,750	46—55	5,800	43—44
Miscellaneous	—	—	4,000	—	6,500	—
Total	40,655	—	56,000	—	86,800	—
Oil-soluble phenolics	—	—	8,000	—	—	—
Phthalic anhydride resins	14,877	—	34,713	—	—	—
Aminoplastics	5,000	—	6,200	35	7,000	35
Vinyl Resins	—	85—125	1,000	65	2,000	50

Compiled from various sources.

TABLE 8

Type MS—Medium shock-resistant type

,, HS—High shock-resistant type

,, HR—Heat-resistant type

The table of minimum properties given in this specification is shown in Table 7, which is reproduced by permission of the British Standards Institution. The specification has not yet been published and I cannot give its number.

PRODUCTION OF SYNTHETIC RESINS IN U.S.A. (IN MILLIONS OF LBS.)

Year	Coal tar acid resins Phenol cresols, etc.)	Alkyd resins (Phthalic anhydride)	Other coal tar resins (Coumarone, etc.)	Non-coal tar resins (Urea, etc.)	Totals
1924 ...	7.5*	—	2.5	—	10.0
1925 ...	8.0*	—	3.0	—	11.0
1926 ...	6.0*	—	4.0	—	10.0
1927 ...	8.0	0.5	4.5	—	13.0
1928 ...	12.5	2.0	4.5	—	20.0
1929 ...	25.0	4.0	4.5	0.5	34.0
1930 ...	18.0	5.0	10.0	1.0	34.0
1931 ...	22.0	6.0	5.0	2.0	35.0
1932 ...	15.5	8.0	4.5	3.0	31.0
1933 ...	31.0*	10.0	4.5	4.5	50.0
1934 ...	42.0*	15.0	4.5	5.0	66.5
1935 ...	55.0*	33.0	6.0	6.0	100.0
1936 ...	87.0	?	?	7.0	?

*Partly or entirely estimated. (Compiled from diagram in *Chem. Met. Eng.* 1937, 44, 97.

TABLE 9.

World Production of Plastics.

It is almost impossible to obtain detailed information on the production of either plastics as a whole or of individual plastics. The country on which the most complete information is available is America and I am indebted to Sir Gilbert Morgan for permission to quote the Tables which he gave in his Presidential Address to the Institute of the Plastics Industry last October (Chem. and Ind. 57, I, 4) Tables, 8, 9, and 10.

OUTPUT OF PLASTICS FOR VARIOUS COUNTRIES (IN TONS)

	1904	1913	1924	1927	1928	1930	1931	1932	1933	1934	1935
Celluloid :											
World output	—	30,000	35,000	—	—	—	—	20,000	—	—	30,000
U.S.A.	—	—	17,000	—	10,000	—	6,500	—	5,900	6,000	8,000
Germany...	—	—	11,000	22,000	—	—	—	5,200	4,500	—	—
France	—	6,000	2,250	—	6,000	—	—	3,000	—	—	—
Japan	—	—	1,000	—	—	—	—	5,000	9,600	—	—
Italy	—	—	2,000	—	—	—	—	600	—	730	—
England	—	—	1,000	—	—	—	—	—	—	—	—
Russia	—	—	—	—	—	—	—	700	—	—	—
Cellulose Acetate :											
U.S.A.	—	—	—	—	—	—	100	327	1,250	2,400	5,500
Russia	(2,800 tons provided for in five year plan)						—	100	—	—	—
Casein (hardened)											
World output	—	—	—	—	—	10,000	—	—	—	9,000	—
U.S.A.	—	—	—	—	—	—	800	700	—	—	—
Germany...	600	1,500	3,000	5,000 (1925)	3,000	—	—	—	—	—	2,000
Czechoslovakia	—	—	2,000	5,000 (1925)	—	—	—	—	—	—	—
France	—	—	2,000	—	—	—	—	—	—	—	3,500
Japan	—	Approximately 700 tons (developing)					—	—	—	—	—
Italy	—	—	—	—	450	320	—	250	—	—	600
England	—	Approximately 1700-2,000 tons per year.						—	—	—	—

TABLE 10

Production figures for plastics for Great Britain are difficult to obtain but the following figures, obtained from the Board of Trade Journal, Prel. Report No. 16 (August 26) are quoted by Sir Gilbert Morgan to illustrate the scope of the industry :—

PRODUCTION OF PLASTICS IN GREAT BRITAIN

	1933 tons	1934 tons	1936 tons
Synthetic Resins:			
Solid or liquid (uncured or cured) ...	8,190	11,410	5,930
Powder (moulding powder)			11,550
Blocks, sheets, laminated		520	735
Casein, celluloid, xylonite, etc.... ...	4,490	5,040	4,695
Cellulose acetate, benzyl, cellulose, etc.	—	250	335
Totals	12,680	17,220	23,245

The following particulars are also taken from the same paper by Sir Gilbert Morgan :—

"During 1935 the world production of phenolic resins alone reached 60,000 tons, of which U.S.A. was responsible for 28,000 tons, Germany 15,000 tons, England 9,000 tons, Russia 1,000 tons, and Sweden 674 tons. Italy's contribution of 1,500 tons is the result of rapid increase from 300 tons in 1928, 500 tons in 1929, 600 tons in 1930, 800 tons in 1931, and 1,100 tons in 1932. Aminoplastics (urea-formaldehyde resins) have also shown increased production, 3,000 tons being manufactued in the U.S.A. in 1935 (3,500 tons in 1936) and over 1,000 tons in Germany. The latter country is now responsible for the major part of the polysytrene output which reached 225 tons and 250 tons in 1934 and 1935 respectively."

Sir Gilbert Morgan adds :—

"Many of the data quoted for plastics production should be accepted with caution, since accurate estimates are difficult to obtain and inconsistencies frequently occur between different authorities, but the numbers I have given indicate at least approximately the order of magnitude of the various branches of the industry."

The Future of Plastics.

I have often said that, in my opinion, the plastics industry has not yet started ; that all its real achievments lie in the future. I do not set up as a prophet but if that statement proves to be somewhere near the truth I shall not be surprised. At the same time, I have no fear but what those plastics which have already established them-

selves and which are used in ways that are suitable to the properties of the material, will maintain their industrial importance. The coming of any new plastic material means that the new plastic is used in industry for those purposes for which its properties make it particularly suitable. Very often the new plastic, because of its new combination of properties makes an entry into a new industrial field, thus opening up a new industry for the use of plastics in general and the total use of plastics is increased. It is inevitable that the field of plastics will continue to expand both in the number of products and the number of uses. One day it may be possible to take certain raw materials, react them in a certain way and so make a resin with predetermined physical characteristics, but that day has yet to come and, meantime, we must make the best use of the known plastic materials with such properties as they have.

You, as production engineers, will probably have occasion to take a very large part in re-designing products for strength, appearance and artistic merit, and re-designing for more rapid and larger production. A great deal has been said of late on the important question of industrial design. I do not mean simply decorative design but design for right use employing the right material in the proper way. Most of the plastic mouldings which are in general use are made by mass production methods from relatively expensive tools. All the thought and design which is to go into the article must, therefore, be concentrated into the first conception of the moulding. Once the tool is made it is too late. As production engineers you will be fully aware of the necessity for this forethought but an impartial observer has to admit that, judging by some of the plastic mouldings which have been made, the article has not been as well designed as it should and could have been. The production engineer, the commercial designer and the artist must all co-operate and think clearly in terms of the new medium if the plastic article is to be properly conceived and successful.

Perhaps one way in which I can illustrate the potential possibilities of the use of plastics is to give on the screen one or two slides showing you products which have been re-designed in terms of plastic materials and I think you will agree that the product using plastic materials is far superior to the old article. I have to apologise for these slides which happen to be taken from advertisements of my own company but you can forget that and just take note of the illustrations alone. The Neophone telephone, in spite of such criticisms as have been levelled at it, particularly from the point of view of dusting, is a marked advance on the candlestick type previously in use. My next slide, showing a clockface from a plastic material, may or may not be the best of its type but there are ample opportunities for designers using plastic materials in all classes of decoration. Bottle caps, which are the subject of my next slide, have filled a

very great need judging by the very large use which has been made of caps in plastic materials in every kind and type of closure for almost every imaginable purpose. My next slide shows a modern door handle which holds out possibilities of cleanliness and finish which the old metal door handle cannot hope to equal. My last slide shows a modern moulded wireless cabinet compared with one of the early wireless sets.

There are hundreds more such applications where plastic materials have taken their place in re-designing. There is no doubt that, where they are rightly used, with a right conception of their proper use, the articles made in plastics are good. The time is already here when every industry must take cognisance of the possibility of using plastic materials when designing any new article. This is true even in such large and well established industries as building, ship-building aeronautical and other large engineering industries, where wood and metal have done good service for many years. Wood and metals have their faults—wood will burn, crack, twist, warp ; metals are heavy and corrode. It is possible that some relatively light but strong plastic material, whose finish is permanent and resistant to the attacks of corrosive atmospheres, may prove to be the right material.

In Table 11 you will find some figures which may be of passing interest. The table is based on one given by Caress in *Chem. and Ind.*, 1936, 2,36. It shows some of the mechanical characteristics of phenolic moulding materials compared with cast iron and I would draw your attention to Column III where the figures for phenolic moulding materials are divided by the specific gravity 1.35 and those in Column IV where the figures for cast iron are divided by the specific gravity 7.5—in other words, a sort of comparison of strengths per unit volume. As engineers, you will know that this is not the whole story but the specific strength considered in this way can be of considerable importance when considering the possibility of the use of plastics for engineering purposes.

The motor car industry is becoming plastic-conscious. The use of all kinds of plastics in the manufacture of aeroplanes is being actively considered for almost every part of the structure ; not the same plastic for all uses but different plastics, according to their different properties, for all the varied parts of the machines—for the body, wings, fuselage, propellers, windows and accessory equipment. Many of you have probably read the extremely valuable paper by Dr. de Bruyne, published in the journal of the Royal Aeronautical Society in July, 1937. This paper covers a tremendous amount of ground in regard to the use of plastics as engineering materials. It shows also some of the vast amount of investigation work which has yet to be done.

I know that I have not been able to do justice to any part of my subject this evening and I am more conscious of what I have omitted

	Phenolic resinoid Col. I	Cast iron Col. II	Phenolic resinoid Col. I div. by SG	Cast iron Col. II div. by SG
Specific gravity ...	1.35	7.5	1.0	1.0
Tensile strength (tons per sq. in.) ...	3–5	14–18	2.2–3.7	1.86–2.4
Bend'g strength (tons per sq. in.) ...	4–6	18–27	3.0–4.5	2.4–3.6
Compression strength (tons per sq. in.)...	10–18	35–50	7.4–13.4	4.7–6.7
Young's mod'us (tons per sq. in.) ...	300–700	3,000–9,000	220–520	400–1,200
Impact strength (ft. lbs.)	0.14–0.22	0.7–1.4	0.1–0.16	0.09–0.19

TABLE 11

than of what I have included. I have tried to survey the field of plastic materials broadly and fairly. I know that I have failed in giving an adequate picture of my subject but I am hopeful that my brief survey has at least helped you to appreciate some of the ramifications of this actively growing and ever widening industry. I hope no one here to-night has in mind that plastics are merely substitute materials for something else. All new materials and all new articles of manufacture at the outset of their career are liable to establish themselves by imitating that which is already established but if they have real life that stage is soon left behind. The early motor car was built like a horse-drawn carriage minus the horse. The early aeroplane was like an engine-driven box kite. The early plastics imitated tortoiseshell and wood. But they are now well able to eschew imitation and to be what they are, something altogether different, something exciting, plastics with a future of their own making.

BOOKS, JOURNALS, ETC.

Books :

Chemistry of Synthetic Resins, Vols 1 and 2, CARLETON ELLIS.

Technology of Plastics, H. W. ROWELL.

Synthetic Resins and Allied Plastics, edited by R. S. MORRELL in collaboration with T. HEDLEY BARRY, R. P. L. BRITTEN, and H. M. LANGTON.

Plastic Moulding, LOUIS F. RAHM.

Artificial Resins, SCHEIBER AND SANDIG. Twenty-five years of Chemical Engineering Progress—Silver Anniversary Volume of American Institute of Chemical Engineers.

Polymerisation (Its applications in the fields of rubber, synthetic resins, and Petroleum), BURK, THOMPSON, WEITH, AND WILLIAMS. British Plastics Year Book.

Journals :

" British Plastics."

" Modern Plastics."

" Plastics."

Transactions of the Institute of the Plastics Industry.

Reprints of Papers :

" Plastics in Chemical Plant Construction," H. V. Potter. Transactions of Chemical Engineering Congress of World Power Conference, Vol 1, pp. 312-342.

" Plastic Materials for Aircraft Construction," N. A. de Bruyne. Journal of Royal Aeronautical Society, July, 1937, pp. 523-590.

" Plastics in a Chemical Works," M. B. DONALD. " Chemistry and Industry," June 7, 1935, pp. 540-546.

" Plastics as Engineering Materials," H. W. ROWELL. " Chemistry and Industry," January 12, 1934, pp. 29-32.

" Properties and Performances of Bearing Materials bonded with Synthetic Resin," by G. R. EYSSEN. Proceedings of the General Discussion on Lubrication and Lubricants, October 13-15, 1937, vol. 1, p. 84.

" The Lubrication of Synthetic Resin Bonded Bearings," by P. BEUERLEIN (p. 8).

" Heavy Duty Bearings of Phenolic Plastics," by H. M. RICHARDSON (p. 249).

" Fabric Bearings for Rolling Mills " by H. ROCHESTER (p. 260).

" The Lubrication of Laminated Synthetic Resinoid Bearing Materials " by H. W. ROWELL (p. 266).

" Some Applications of Fabric Bearings," by E. WATSON SMYTH (p. 277).

Above reprinted in the Proceedings of the General Discussion on Lubrication and Lubricants, October 13-15, 1937, vol. 1—published by Institution of Mechanical Engineers.

Discussion.

MR. CHAPMAN : I quite agree with our Chairman that we have listened to a marvellously well-balanced discussion on plastics. Mr. Dring has specified every type and you will realise that, in order to keep up-to-date in his own particular field, he has studied and studied well the other branches. We can learn from his paper that there is some truth in the statement that a plastic is a thick "vicious" substance. The chemistry of these materials leads us nowhere and I may confess that theory is a long way behind practice in this industry. The sting of the whole paper is, I think, in the tail, that is, that these plastic products are raw materials of construction. I personally very much regret that this was not further dealt with by our lecturer this evening. He is quite capable of so doing and I I am quite sure that he has sufficient information for another full paper similar to the one we have just heard. Laminated bearings solve many problems in industry, and those of you who have any problems where lubrication is difficult should investigate laminated bearings where water is quite a sufficient lubricant. In some cases no lubrication is required at all. There are numerous indirect applications of plastic materials on which I think Mr. Dring might well have let himself become a prophet. One further application which might have been mentioned was the possibility of making plastic materials, particularly of the thermosetting type, in continuous lengths of standard section. I wish, frankly, that Mr. Dring had been able to give us more time on those things on which he is an expert and I hope that some people will ask positive questions. Mr. Dring can answer them. We wish in the plastics industry to have ideas given to us.

MR. BATES : I would just like to ask this question, as an engineer. I have carried out a number of experiments during the past six months on the particular line our friend here has spoken about, and I find that this plastic material only " flatters to deceive." When I say that, I mean it always seems to break down at the critical point. I would like to know—is it comparable with a metallic substance ?

MR. DRING : I was very careful to point out that plastic materials should not be considered in any way as substitute materials and could only be properly used with the right conception of their unique properties. None of these plastic materials can replace metal, as metal, where the properties of metal are essential. In general, they do not have elasticity—in fact they are generally brittle ; when submitted to tensile pull they do not extend but immediately break. They have no yield point and cannot be compared with metal in

that respect. I wonder whether the speaker has a specific application in mind so that the question could be discussed in concrete terms. I would point out that if any particular application is unsuitable—and there are many applications which are unsuitable for plastic materials—no reputable manufacturer of plastics would want to see a plastic material used. One often finds that plastics are used without a complete conception of the properties of these materials and, in that case, they may be used in ways which are unsuitable for them.

MR. BROOKS: I should like your advice upon the possibility of using plastic materials for radiator construction, i.e., as a substitute for the well-known copper tube.

MR. DRING: It does not seem to me to be a very satisfactory application.

A VISITOR: As an electrical engineer, I am rather interested in this matter. In the past I have had an idea that bakelite was used for very expensive things. I should like some details in regard to the softening point and also some information in regard to mouldings. I understand mouldings are very expensive to make.

MR. DRING: I purposely avoided mentioning any question of moulds and mouldings, owing to the fact that in a month's time you are having another lecture covering this whole question. I referred in my paper to the softening point of various thermoplastic materials and I also referred to the heat resistance of various moulding materials.

A MEMBER: May I ask Mr. Dring's opinion on transparent plastics. Is it oil-resistant? Must it be moulded to size or can it be purchased in sheets?

MR. DRING: Transparent plastics can be bought in sheets or moulded to shape. Transparent plastics can be obtained which are resistant to oil and suitable for oil gauges and quite stable as to colour.

MR. MCGUIRE: I have been extremely interested in the lecture this evening and I must congratulate the lecturer on his thorough knowledge and understanding of his subject. I noted his remarks about certain liquids which have a softening effect on some bakelite compounds. I am wondering how far we could go in the use of these for the manufacture of small lot Bakelite components. For instance, a little while back I was called upon to manufacture about 200 bakelite channels, walls of channel to be $^1/_{16}$ in. thick. The quantity was too small to permit a mould to be made, on account of expense. The method I took was to obtain several pieces of very thin canvas bakelight sheet, steamed them for a time, then placed them in a gas heated channel tool for a length of time. The method was costly and

had to be carefully carried out, on account of blistering. On another occasion I had to bend hard American fibre of $^{5}/_{16}$ in. thickness into a squared U about 22 in. long, 8 in. wide, and 18 in. high. The method here was again steaming for a certain length of time and placing in a gas heated tool for a further period of time. This again was a costly operation and great care had to be exercised for fear of blistering. Now I am wondering if our lecturer could tell us whether I could have used any of the liquids, such as spirits or acids, he has mentioned this evening which would have had a softening effect on the materials I have mentioned, so as to be able to form them into the required shape, thereby doing away with the heating by gas and steam and considerably cheapening the process of manufacturing.

MR. DRING : I am afraid there is no suitable solvent which would help you in the way in which you ask.

MR. SANDY : I must confess that to-night I have been somewhat overwhelmed by the imposing array of long names ; perhaps I am not the only one. I think I sense an invitation by the opener of the discussion to production engineers to offer ideas for new avenues of development. This is unfair, as the skeleton is kept very carefully in the cupboard, namely the design and manufacture of moulds and the problems of moulding technique. Apparently we must await the next lecture when the skeleton is revealed and then we may be in a better position to offer ideas. The moulding problems are very real and have a limiting effect upon design. It appears only possible to mould articles of uniform section otherwise curing difficulties arise. Here seems a field for investigation by the chemists. There was a brief reference by Mr. Dring to the artistic side of plastics; from what I have seen it would appear that firms send a youth from the office to an Art School for training ; surely it should be the other way round, and a promising youth from an Art School should be taken and given training in the works to learn the " snags " of production.

MR. PHILLIPS : I am rather interested, firstly, in the cementing of laminated sheets. It is quite possible that laminated sheets can be cemented together and I should like to know whether Mr. Dring could give us some idea of the strength of the cementing in laminated sheets which would give the necessary strength which an ordinary aeroplane propeller has to contend with. My second question is on distortion. In the case of windscreens for aeroplanes, I understand that the material has a low softening point and aeroplanes travel through tropical countries with a wide range of temperature and severe climatic conditions.

MR. DRING : With regard to laminated propellers, I could outline a whole range of possible experimental work which might be carried

out. A lot of work has already been done and I would refer you to Dr. de Bruyne's paper "Plastic Materials for Aircraft Construction" (Journal of the Royal Aeronautical Society, July, 1937, page 523). With regard to material for windscreens, I must point out that it has been used in considerable quantity in aircraft but I have no definite information as to what the distortion would be under heat. I doubt whether the trials on this material would have got to the present stage if the material were really unsuitable.

MR. BATES: As engineers, we make a mould for producing an article and we very often require the article to be to very close limits. We make up a special mould and find that the article does not compare with the limits required owing to the fact that synthetic resin requires larger limits than we are used to. Can you suggest any way that is possible to hold mouldings to finer limits?

MR. DRING: As manufacture improves it will probably be possible to get to even closer limits than at present. The question of getting accurate limits in a moulding is not a simple one because the contraction of the moulded article on cooling is different from the contraction of the mould. It is a matter of expert moulding technique to get really close limits in a moulding.

A MEMBER: I understand that canoes are being pressed up by using plastic laminated board. Can you give me any information as to the degree of success registered? I imagine our safety first shields for machinery might be made very cheaply by that method without expensive moulds.

MR. DRING: I have not had an opportunity of seeing that type of manufacture and I would not care to express any opinion.

MR. CHAPMAN: The moulds are quite simple—plywood is bent under double curvature to any shape and will retain that shape, but very large presses must be used.

MR. STOREY: I would like to ask if it is possible to mould any normal thickness articles in celluloid on a wooden or wax mould. I am fully aware of the cost of steel moulds. One of the difficulties many manufacturers have to meet is the placing before their public what is in fact a finished experimental moulding, that is to say, you have your article, you want to know if it is going to sell on the market and you cannot wait for the mould makers or take the risk of making expensive moulds. In many cases it may be possible to make up a wooden mould like the pattern for a casting, without going to the expense of a very elaborate mould, I thought perhaps it might be possible, for example, to carve it out of wax, and deposit a layer of copper, and if such could be used for the moulding of a few sample articles in celluloid.

MR. DRING: Various ways have been tried for making small

numbers of articles in the way you suggest but, as far as I am aware, none of them has been really successful.

A MEMBER : Can you tell us anything about moulding spectacle frames ? I find they always break after moulding.

DR. REDFARN : About cellulose spectacle frames, I am wearing a pair myself made by a firm with which I have some connection and I rather suspect the gentleman is using a cheap and inferior material. If you pay the price you can get spectacles that are reliable, alternatively the cause may be found to be working with the mould too hot The chief point I would like to make is that I am appalled at the ignorance of production engineers concerning plastic materials and the capabilities of plastic materials. Another point is the way in which production engineers endeavour to use plastic materials. If I wanted to use a laminated bearing material, I would not waste my time experimenting ; I would go the people supplying the laminated material and ask what they recommended for use, then approach the manufacturers and obtain the information I required.

MR. BATES : I cannot let that go without a reply. No doubt the gentleman is a chemist. I am an engineer, and he must not conclude that the engineer does not go to the right people and find out all the information it is possible to get beforehand, before he asks a question. When a new material comes along, the first thing an engineer does is to compare it with other substances—a new thing in any shape or form can only be judged by comparisons.

A vote of thanks to Mr. Dring concluded the discussion.

MODERN PLASTICS—MANUFACTURE AND USES.

Joint Paper presented to the Institution, Yorkshire Section, by H. Jones, B.Sc., and J. Prior.

(NOTE.—*Owing to indisposition Mr Jones was unable to attend the meeting: his part of the paper was read by Mr. Prior, who was supported in the discussion that followed by Mr. A. Hill*).

Part 1 (Mr. Jones)

AS the first speaker, I would like to say that if some clearer idea is obtained by you concerning the properties and uses of present day plastic materials, both Mr. Prior and myself will consider ourselves amply repaid for this visit. We certainly would like to create the impression among you that plastics are materials to be considered when new articles or appliances are being evolved, just as at present you consider whether you shall make an object in metal, wood or stone.

First of all there are some points I would like to stress before dealing with my portion of the paper. The first relates to the use of the term " plastics." As far as the lay person knows plastics are such products as bakelite, celluloid and even those materials which journalists are prone to call " products made from milk ! " Plastics have been known and used from time immemorial—Noah is reputed to have used pitch in the caulking of the Ark ; and pottery is an art which has been in vogue for centuries and involves the plastic properties of clay and so on.

These products, in common with the present day synthetic plastics, owe their usefulness to the fact that at some point or other during their manufacture, they exhibit plasticity, that is they can be shaped by the application of simple mechanical methods of deformation and the like. In the case of clay the plasticity is due to the presence of water. So it is with present day casein plastic, but additional heat action is necessary before it can be worked efficiently. With resinous plastics, such as the phenol-formaldehyde and urea-formaldehyde types, both heat and pressure are required to make the material flow and take up a predetermined shape. Modern plastics of these two types have a peculiar property in that protracted heat-treatment induces a hardening effect so that in the

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final product they are devoid of plasticity. They thus compare with metals in showing a wide elastic range with an abrupt yield point. The amount of flow of which they are capable is very much less than with malleable metals such as lead and copper and they can, in fact, be considered as rigid bodies.

The property of the initial materials in being plastic under certain conditions is interesting because it is related somewhat to the fluidity one associated with liquids, such as water, and metals when in the molten state. I think I can safely say that the widespread use of metals is due to the fact that they can be shaped while in the fluid condition—i.e., after melting, they can be cast to a rough shape. This applies also to plastic materials with a slight modification, since they do not actually become pourable but become sufficiently soft to be shaped in a mould by the pressure influences I have mentioned. The condition of a raw moulding material during the shaping or pressing operation corresponds roughly to that one would find with steel in the *incipient* molten state, or, alternatively, at the point where it was showing an appreciable yield as the result of the application of high stresses.

A further difference between the moulding operations of the plastics trade and the steel and iron trades, is that with the former an object of high finish and close dimensions is obtained from the mould. Plastics are moulded to finished dimensions and require no other treatment than the removal of certain very light " fins " or " flash lines," as they are termed in the trade. The whole process is very much akin to the die-casting of metals on a refined scale. In fact, certain novel types of plastics are now being manufactured into useful components as a result of the use of " injection moulding "—a branch of the trade Mr. Prior will no doubt explain to you.

The temperatures of the moulds and materials during the plastic moulding operation are of the order of 140-180°C., and the times required to effect softening and curing actions vary according to the thickness and weight of material going into the article in question. Times usually vary from about half a minute to three or even more minutes. The pressures employed vary from about a half to two tons per sq. in. over the effective area of the article to be moulded, though an average figure is one ton per sq. in.

The whole crux of plastic moulding lies in the ability of the material to soften under the application of heat, then to flow under the applied pressure, so taking-up the shape of the mould and then—what is very important—to take on a rigid condition due to the chemical reaction within the moulding material. This series of actions takes place in the times I have specified, and includes also ejection of a hot rigid article from the mould. These events comprise the so-called moulding cycle, and when I say that as many as 100 and more cycles per hour have been achieved in the manu-

facture of certain small articles weighing perhaps one or two ounces, you will appreciate that here in the plastics industry is an intriguing method of production. As production engineers, I suggest that you should make yourselves familiar with this new and efficient method of producing objects and components of all conceivable types.

The best known moulding material is available under the name of "Bakelite," though many other similar products are now being sold in this country—e.g., Mouldrite, Elo, Rockite, Beetle, etc.—these being various trade names for that important type of plastic which sets up on heat treatment as I have described. The chemical names for these products are as follows; phenol-formaldehyde, urea-formaldehyde, cresol-formaldehyde, and so on. These are the names of the raw chemical materials used in their production.

The hardening action which takes place during the moulding operation is known in chemical language as "polymerisation"—this meaning a linking up of simple chemical compounds to form new ones of extremely complex natures. Polymerisation is at the basis of the formation of synthetic resins, which in turn are responsible for the formation of plastic materials. The characteristics of a polymerised resin material include those of inability to melt or soften under heat action and this has led to the adoption of a class name for this class of plastic—i.e., "thermo-setting." Finished mouldings will show a slight yield under stresses if these are applied at temperatures in the region of 150°C.—the real point being that they cannot be re-used in further moulding operations. Any rejects or flash trimmings are definitely scrap material and are therefore to be reduced to a minimum. Moulded products of the thermo-setting class are unaffected by water, external weathering influences and solvent attack, such as immersion in alcohol and the like. In essence, they show a high degree of stability and inertness. Their physical properties I shall refer to a little later, since these can be modified considerably.

There is another class of plastic material in use which, as you may have guessed, is "thermo-plastic"—that is, it does not undergo the chemical hardening or polymerisation effects on heating. In the moulding of these products similar tools, pressures and temperatures are used, but it is essential to give the material a cooling effect—a sort of solidifying process before it can be ejected from the tool in a rigid state.

The differences between the two types of plastics are bound up with their chemical structure, and it is possible by the correct choice of starting materials and the proper manipulation of the chemical processes involved to make either type of plastic. These manufactures are in the hands of the plastics chemist, just as the manufacture of various steels and alloys are in the hands of a metallurgist, so that I do not intend to inflict any details of these

processes upon you to-night. If anyone present does wish to learn more of the fundamental differences between the two types I should be very happy to go into the matter later, but for the present more important points have to be covered.

The thermo-plastic materials can of course be re-softened and any reject articles can be re-moulded after being broken down to a rough powder again. Under normal temperature conditions they behave as rigid bodies with an attractive degree of impact resistance. Their chemical and heat resistance is not quite of the same order as with the other class though their use is expanding very rapidly on account of the elimination of the curing period so necessary with the thermo-setting compounds. This enables them to be injected into cold moulds and gives rise to alarmingly high rates of production in injection moulding.

Manufacture and Properties of Moulding Materials.

In explaining to you the nature of the moulding powders used in the trade, I would like to point out that they are very similar to concrete, in that they generally consist of :—

(*a*) A binding material such as a synthetic resin.
(*b*) Filling agents, such as wood meal, asbestos, etc.
(*c*) Certain other auxiliary agents, such as accelerators, etc.

The properties of a concrete mass can be modified by changing the amount and nature of the filling or loading material and so by the variation of amount and nature of resin or filler, and so plastic materials can be endowed with varying and desirable properties.

As I have already stated, the main plastic materials of to-day are the " thermo-setting " types and these are combinations of synthetic resins with different types of filling or loading agents. Certain other auxiliary materials are added for reasons which will be apparent later, but generally these control the rate of cure and the colour of the finished object.

The main resinous materials in use are as follows :—

Phenol-formaldehyde, cresol-formaldehyde, urea- and thio-urea-formaldehyde.

The principal filling agents are :—

Wood-meal, cotton-flock, fabric-pieces, asbestos, mica, and paper-pulp.

The amounts of resinous bonding agent and filler are approximately equal, though an increase of resin content usually extends the degree of flow of the powder and makes it more costly.

Reference to Table No. 1 will show the different physical and mechanical properties of the above combinations and will also give some idea of the manner in which they compare with other materials of construction. Naturally, these figures refer to the finished plastic in its usable condition.

GENERAL PROPERTIES OF PLASTICS

PLASTIC			APPEARANCE AND COLOUR EFFECTS	METHODS OF USING Moulding, casting, etc.
Binder		Filler		
Phenol-formaldehyde resin	Moulding powder	Woodmeal .	Opaque—all but white.	Compression and extrusion moulding.
		Asbestos ...	Do.	Do.
		Fabric ...	Do.	Compression moulding.
	Laminated	Paper ...	Do.	Sheet, rod, and tube.
		Cloth ...	Do.	Do.
	Cast	None ...	Glasslike—all colours.	Cast to rod sheet, etc., and machined.
Urea resin .		Cellulose ...	Translucent and in all colours.	Compression and extrusion moulding.
Styrols ...		None ...	Glasslike and in all colours.	Compression and injection moulding.
Acrylate ...		None ...	Do.	Compression, casting, and injection.
Casein ...		None ...	Do.	Extruded—sheet, rod, and tube.
Cell. acetate		None ...	Do.	Compression—injection, sheet, and rod.
Cell. nitrate		None ...	Do.	Sheet, rod, and tube. Inflammable.

TABLE 1

Other moulding materials are made, chiefly of the injection moulding type which contain a minimum of fillers, since extremely free flowing materials are required to produce objects by this method. They are the thermo-plastic moulding materials and briefly are as follows :—

Resins :—Polystrene, methyl-methacrylate, vinyl acetate, etc.

Non-resins :—Poly-vinyl chloride, cellulose acetate, benzyl cellulose, etc.

The non-resinous type really consist of a homogeneous mixture of the base substance I have named and a plasticising agent. This compound shows all the properties of a resin in that it will soften and can be moulded under normal conditions of thermo-plastic moulding. These can all be moulded in the ordinary compression type of mould such as is used with the other types of plastic but are generally employed in the newer injection operations where the defects of lack of thermo-setting properties do not matter.

Laminated Materials.

These need a few words of explanation since it will no doubt have been obvious to you from the figures I have given concerning mechanical strengths, that they have very much better properties than the

ordinary moulded products. As the name implies, they are laminated products in the true sense. The ordinary methods of moulding do not apply, but the essentials of the process are present. Thus, the manufacturing operations consist of the impregnation of paper or fabric with a solution of a thermo-setting synthetic resin of the phenol or urea formaldehyde types. This is done by continuous methods and the machine also enables a drying stage to be incorporated. The rolls of resin-impregnated paper are then cut into lengths and stacked together, there being from 10 to about 100 layers in each pack dependent upon the final thickness to be attained.

The packs of papers so prepared are placed between polished steel sheets and loaded into a multiple daylight press provided with steam heated platens. Heat and pressure are slowly applied and the same sequence of events occur as is the case in ordinary plastic moulding. That is, the resin softens under the heat action and all the sheets bond together, giving a homogeneous mass. The heat and pressure action are prolonged and the customary hardening takes place after a number of minutes. The solid packs are then cooled slightly before ejection from the press in order to minimise warping effects and the sheet is then ready for use.

ELECTRICAL PROPERTIES OF PLASTIC MATERIALS

PLASTIC			BREAKDOWN VOLTAGE volts per mil. at 60 cycles	POWER FACTOR at 60 cycles
Binder		Filler		
Phenol-formaldehyde resin	Moulding powder	Woodmeal ...	300–500	0.04–0.30
		Asbestos ...	250–400	0.10–0.30
		Fabric ...	300–450	0.08–0.30
	Laminated	Paper ...	400–1,300	– ?
		Cloth ...	150–600	– ?
	Cast	None ...	300–450	– ?
Urea-f resin		Cellulose ...	650–720	0.03– ?
Styrol ...		None ...	500–700	0.003– ?
Acrylate ...		None ...	480–	0.06–0.08
Casein ...		None ...	400-700	– ?
Cell. acetate		None ...	800–850	0.04–0.06
Cell. nitrate		None ...	600–1,200	0.06–0.14

TABLE 2

Generally this type of material is used extensively in the electrical trade and is cut to shape from the rough sheets. Punching is also employed with thin cross-section materials and milling is also resorted to in the manufacture of gear wheels from fabric filled

sheets. These give rise to a variety of so-called silent gears now very much in vogue.

Laminated materials are now finding a further and extended use, as the unheated pack of resin bonded papers can be pressed in a crude type of mould. This method has recently been used with considerable success in the manufacture of what are termed "bakelite bearings." I can state that these are a revolutionary introduction to the engineering trades and possibly many members present to-night have already made their acquaintance. Developments in this field are being reported almost daily, and the investigations are being conducted with considerable zest.

MECHANICAL PROPERTIES OF PLASTICS, ETC.

PLASTIC			Tensile strength 1,000 lb./sq. in.	Impact resistance ft. lb./ASTM notch	Brinell hardness 2½ mm./25 kg.	Specific gravity 20 C.
Binder		Filler				
Phenol-formaldehyde resin	Moulding powder	Woodmeal .	6–11	0.10–0.28	30–45	1.35 —
		Asbestos ...	5–10	0.11–0.36	—	1.85 —
		Fabric ...	6½–8	0.40–2.40	—	1.37
	Cast Laminated	Paper ...	6–13	0.40–1.20	24–40	1.31
		Cloth ...	8–12	0.80–5.20	30–45	1.34
		None ...	5–12	0.10–1.50	30–45	1.32
Urea-f resin		Cellulose ...	8–13	0.70–1.50 c-unn.	48–54 500 kg/10 mm.	1.45
Styrol ...		None ...	5½–7	0.16–0.25	20–30	1.05
Acrylate ...		None ...	7–9	0.25–0.50 c-n.	18–30	1.08
Casein ...		None ...	7–8	1.00– ?	23–	1.35 —
Cell. acetate		None ...	3½–10	3.00–12.0 c-n.	6–7½ 10 kg.	1.30 —
Cell. nitrate		None ...	5–10	3.00–12.0 c-n.	8–11 10 kg.	1.30 —
Copper ...		... ...	19–34 ult. —	—	90	8.93
Steel ...		... ...	80–120 ult. —	—	190–200	7.85

TABLE 3

It is possible to make synthetic resin bearings using the type of fillers mentioned under the previous heading of fabric filled thermosetting powders. These are moulded to complete dimensions and where very high loads are involved, at slow speeds, give excellent service. The usual lubricating materials are water (which also assists in the cooling of the bearing), and I am informed that the energy consumptions are in the region of 70% of those found with

ordinary metallic bearings when used in connection with roll-mills. The developments at present under way relate to the production of plastic (N.B.—not really plastic) bearings which have had incorporated as a filler a certain amount of graphite material.

Since I believe this aspect of the subject to be of great interest to engineers, I would like to quote the following notes from a communication received by us from Messrs. Francis Shaw & Co. Ltd. of Manchester—this firm being one of the few to adopt plastic materials in the manufacture of bearings.

Water Lubricated Bearings.

The new bearing material, made from synthetic resin bonded fabric, has been tested on steel rolling mills, paper mills, and other applications with great success. The main advantages are as follows :

(1) Four times longer life than phosphor bronze and the like.

(2) Reduction of power consumed due to the low co-efficient of friction of water lubricated bearings compared with oil lubricated metals.

(3) Saving of spoilt sheets due to contacting with greasy surfaces.

(4) Savings in lubrication materials.

(5) Inability to score roll necks even with excessive heat.

Metallic bearings are composed of hard crystals embedded in soft matrix and, properly lubricated, work very well. When, the lubricant becomes thin or fails, trouble arises in that the bearings become hot and the crystals tear at the roll neck, and, as the heat, increases, the softer matrix recedes and wear ensues. The worst that can occur with a plastic material bearing is a carbonising of the surface without effect on the roll neck.

The amount of water supplied to the bearing varies with the load and speed, but should be sufficient to keep the maximum temperature less than 300°F. The best average temperature for working has been found to be about 200°F. The material is practically non-absorbent and is unaffected by oils, water and the like. Therefore the materials undergo no change or deterioration whether idle or in use. In the conversion of existing machines to this type of bearing, it is necessary to install new bearing blocks which are machined for water lubrication.

Summary.

There are literally hundreds of facts concerning the manufacture of appliances from modern plastic materials which I would very much like to mention. Needless to say time does not permit and I want now to give over the rostrum to Mr. Prior who will give you

more information of the production processes used in the plastic moulding trade. We have brought a large number of specimens to show to you to-night in the hope that your interest might be further stimulated by these wonderful materials. I would suggest that you examine these prior to the discussion, since some points might arise which could only be provoked by such an examination.

Plastics are not perfect materials and show only certain of the virtues we demand of constructional materials, Nevertheless, the few virtues they do exhibit form a unique combination which is not found in other products and this is the justification for to-night's paper.

Moulding methods and faults.

The following brief collection of factors controlling the proper moulding cycle is not offered as a complete panacea but merely as an indication of points to be watched and correctly adjusted before perfect moulding can ensue.

If the following factors are exerting their correct influence no faults should occur.

(1) Use of correct weight of moulding powder—determined with new mould by experiment. Fault is apparent as an incomplete moulding with a saw-dust type of surface.

(2) Correct disposition of the powder or pellets in the mould. This leads to the even filling of the mould whereas improper placing causes incomplete mouldings with thick localised flashes.

(3) The pressure to be exerted is chiefly determined by the effective area across the mould, i.e., that offered to the line of application of the hydraulic pressure. Some allowances are made for intricate mouldings and where the article has a large amount of depth. Lack of pressure leads to improper filling of the mould cavities, incomplete mouldings and/or thick flashes.

(4) Correct temperature conditions enable the cure to be effected in a minimum time. Low temperatures lead to poor flow of the material and very slow curing rates. High temperatures are used up to a point where the material just begins to show the effect of cure on the surface of contact between the powder and the mould. This is termed pre-curing and is to be avoided.

(5) Time of moulding bears a relation to the temperatures used and also to the nature of the particular powder in use. The extremes are :—

   (*a*) High temperatures and long cures—heat blisters, due to the decomposition of the material.

   (*b*) Short cures due to insufficient curing time and too low a temperature—gas blisters due to the surface being slightly soft and thus not retaining any internal pressures due to gas formation.

A certain amount of vaporous material is nearly always found in general grade powders since these contain up to 3 and 5% moisture.

(6) Large areas require to be cooled under a former in order to avoid warping due to the uneven cooling rates of different cross sections.

Generally speaking, moulding powders are available in different degrees of flow and curing time and experience alone can indicate which is the correct combination for the most efficient production under given conditions.

Part II (Mr. Prior)

You have heard from Mr. Jones, with admirable clarity and precision, details of the materials we are to consider. It will be my aim to follow—with due humility, as is fitting from a mere engineer to a chemist !—and outline how we use the materials, and change these rather wonderful ingredients to the components and articles of utility with which we are all familiar.

Our industry, whilst we believe it has passed its birth pangs and is healthy and flourishing, is still a child of tender years, and consequently is not in any sense either hide-bound or stereotyped, and amongst its experts, if you will forgive the arrogance—there are often cleavages, all sides of which can be supported by logical reasoning and even by practice.

To produce almost all synthetic resin mouldings, we need (1) presses, and (2) tools, and to finish them we need some measure of equipment to trim off the flash or spue, and, in certain instances, equipment to polish. Time will not permit my entering into a detailed discussion of any of these items. I will therefore briefly outline the commonest and most typical plant.

Firstly, the presses. These are usually four-pillar, single daylight hydraulically operated units, with heated platens both top and bottom, and vary in capacity from 25 tons to 350 tons, by 25 to 50 tons steps, after which they are generally designed to a specification and go up in this way to 4,000 tons capacity. Up to 500 tons they are usually fed direct from a dead weight accumulator at one ton per square inch pressure, which in turn is energised by a straightforward three throw pump. The larger presses are often boosted by hydraulic or steam intensifiers. Almost all modern presses are fitted with prefiller gear to use up the spent water and conserve that from the accumulator, this cutting down the size of this part of the plant. An extra cylinder with short stroke, say 3 to 4 in., is often added in the base of a downstroke press for purposes of ejection of mouldings.

For all thermo-setting resins, i.e., the phenols and the ureas (as outlined by Mr. Jones), heated platens are required, the heating medium being either electricity, steam, or gas, in that order of popularity, and temperatures of 310° to 400°F. are required for phenols and 275° to 320°F. for ureas. One point to note here is that a much wider degree of temperature variation can be permitted on phenol powders than in ureas. The heated platens are usually thermostatically controlled, where possible independently, and this is, I think one of the reasons for the popularity of electricity.

It will be fitting, whilst on the subject of presses, to say a word or two on "pressures," as it will help us to a realisation of the conditions imposed on the moulds. Generally speaking, phenols require a pressure of one ton to the square inch upwards, and ureas from one and a half tons upwards, although it is usual to allow a margin over these figures and often much higher pressures are required, depending on the form of article to be produced, and also, to a degree, on the powder, certain of the special purpose powders requiring pressures up to double the rates given, which should be regarded as a minimum only.

I omitted to make clear that my foregoing remarks refer to the thermo-setting resins, I will refer to the thermo-plastics separately later, as the technique is quite different, as is the plant.

Let us now briefly consider the moulds in which the material, under the action of heat and pressure, make the change. As engineers, you will have already foreseen that under pressures such as I have just mentioned the designer has to meet conditions of extreme severity, and yet must produce forms of great delicacy. It then becomes at once apparent that special steels are required, and when I state that, in the main, the finish on the article as you know it is imparted in the mould, and that the mould must withstand surface abrasion from the powder, you have the three principal needs to be met.

The most used steels are nickel chromes, and the moulds are heat treated to give a very dense internal structure, one that will not sink under the pressures, and also a high degree of surface hardness.I have heard it said by experts that 450 brinnell is hard enough to resist the abrasion of the powder, but my ideals of a tool are a core hardness of 450 brinell, or approx. 100 tons tensile, with a skin hardness of 60 to 63 Rockwell. I can then feel reasonably confident my mould will resist maltreatment, and can be expected with reason to have a life of 500,000 mouldings as a minimum.

There are other conditions to be met, but I crave your indulgence, on the grounds of insufficient time, to leave out the consideration of them, or this paper will develop into a treatise on moulds. Suffice to say that the moulds are one of the corner stones of the industry, and require a high skill and specialised knowledge to produce, as

the surfaces must be polished to a mirror finish, and all toolmarks scratches, etc., must be entirely eliminated if we are to have a good moulding. Further, in view of the high pressure, inserts or loose pieces are to be avoided wherever possible, and even when they cannot be avoided, must, unless of robust dimensions, be in the direction of the press closure. To give a simple instance, if I desired to mould a block, 2 in. square by $\frac{3}{4}$ in. thick, and desired to put a $^{3}/_{16}$in. hole in it, I could just about manage to mould it through the thickness if my block were laid flat down and the hole axial with the stroke of the press, but I should have very little chance of moulding in a similar blind hole in the side. I should probably bend or break my pin the very first time. If you will cast your mind over some of the mouldings you have seen from time to time you will then appreciate better the skill behind the design of some of the moulds.

Before leaving the subject of moulds, I would like to mention that from the mould to the finished moulding, there is a shrinkage allowance to be made which is .005 in. to .008 in. per inch, this varies slightly with the characteristics of the powder, but once known is consistent. The accuracy of a moulding however when considered from a precision engineer's view point cannot be regarded as very close. For commercial work, a tolerance of plus or minus .004 in. is usual, although in special instances plus or minus .001 in. has been maintained. This variation is due to a number of reasons: (1) Power variation; (2) temperature variation; and (3) curing time. It can however be kept at a minimum if all the above points are closely watched.

I must get on to the angle of the subject which I regard as your "meat," but firstly let me make good an omission from my list of plant requirements, the preforming or tableting machine. The volume of the powder compared with the volume of the finished moulding is from three to four to one, depending on the characteristics and on the size of the granules. This question of volume renders it necessary to allow in the tool for an excess loading, and, on this ground plus the inconvenience of handling, it is now almost universal practice (where the quantity to be moulded permits) to make the powder into a tablet or preform.

This preform has a volume of only one and a half to two times that of the finished moulding, is much more convenient to handle and, within a limit of a few per cent, is a correctly weighed charge. We thus make the first step in the production of our moulding—i.e., to get the "powder" into a convenient and weighed out state. Please do not take the view that it is only a shortsighted man who does not tablet, for small quantities, certain types of work, and very fragile mouldings, it is quite possible that powder is the best way,

although these I agree from the sheer production angle are the exceptions.

Let us assume, however, that we have our preforms or our powder ready to be weighed or counted out of material stores. We have also, I trust, a general idea of the press ; it is therefore opportune to describe an imaginary mould such as would line up with modern practise. We are, shall we say, engaged in producing an electrical plug top 2 in. diameter, and are working this in a 120-ton press with a mould containing 25 impressions, the cross area of 2 in. diameter is 3.14 sq. in., which multiplied by 25 equals 78.5 sq. in. total area, giving us 1½ tons per sq. in., which for this class of article is sufficient. Our mouldings are to be ejected from the bottom ; we have therefore two mild steel bolster plates, aligned by three or four hardened steel dowels and bushes, the dowels being 1¼ in. to 1½ in. diameter ; 25 holes are bored into the plates, and in each we have a hardened mould impression, the female or die half in the bottom and the male or punch half in the top ; also in the bottom half of every impression are two pins level to some convenient face, and going through a cast-iron grid, and into a built up mild steel frame, known as the ejector frame, the pins are shouldered and locked into this frame which, by connecting bars, is linked up with the ejector ram in the base of the press, which ram is usually operated by an independent control valve.

We have now press, tool, and powder, and we can assume that we have a male operative of the semi-skilled grade.

We have now to describe : (1) Temperatures, and (2) Curing time, and (this is a direct production problem) we must ensure that the time to load and unload the press is kept to a minimum. I might mention here one aid to this, which is known as a loading board. This consists simply of a perforated plate, usually timber, fitting and registering over the mould with a slide or shutter forming the base of the holes ; the preforms (and on occasions powder) are placed in each hole, which, of course, are appropriately over the mould cavities ; the base shutter is pushed in and brings under each hole a series of others to correspond, thus dropping the charge into the mould cavities ; this is removed and the press closed.

To arrive at temperatures is reasonably simple and is really a matter of experience. If the material is " phenol " then a start at 320°F. is recommended, or, if " urea," then 290°F. and a cure of approximately one minute each $^1/_{16}$ in. in thickness should at least be good to start.

It is, however, usual when commencing a new job and new tool to give the first few cures extra time, as nett result of over curing is a spoiled moulding only, but if we undercure we have then a semi-solid mass which adheres to any corner or crevice, and we can

reckon perhaps half an hours wasted time to clean. My own method of starting up a new job is, I think, typical, and that is to give both overtime and also overweight. By the thickness of flash or spue one can easily tell the correct charge, and then it is logical action to bring down the cure by 15-second stages to find the minimum time to cure. The question of temperature is not quite so simple, as it depends on the speed at which the charges can be loaded into the press and the press closed. The reason is that if the temperature were very high and the press slow in closing we should get what is known as " precure," as, of course, you will recall from Mr. Jones's remarks that our powder cures by heat. Another governing feature is the thickness of wall of the moulding in question. To take two extremes, if we had an article 1 in. thick, we must allow the heat to go through the mass and cure out without overcuring the outside, thus too high a temperature cannot be maintained here. On the other hand with an article such as a lampshade with a wall thickness approximately $^1/_{32}$ in., cures up to 120 per hour have been made—literally what is termed flash curing.

You may wish to know what are the signs of undercure and overcure, etc., Mr. Jones will be more able than myself to give these.

If our moulding is to work to some specifications, then the very earliest step after we have secured what appear to be good mouldings is to send them to the laboratories to be scientifically tested, or alternatively (and possibly additionally) to the customer, as many apparently perfect mouldings have been found faulty due to one or another cause when subjected to properly controlled tests, and these tests have the additional advantage of revealing the flaw, thus giving us a guide at least to the eradication.

The moulding process, once we have found weight, temperature and curing time, is literally only a matter of repetition and is really very simple. The only points to watch are to ensure that the operative loads up his preforms, or at any rate in some way prepares his next charge, whilst the one in the press is curing, and also that the time taken to remove cured mouldings and clean the press is kept to a minimum.

For any given moulding most features, once ascertained, are constants, I refer now, of course to weight, curing time, etc. A point of interest arises, therefore, as to what other points are there which can affect production, and ensure that the article is being made at the cheapest possible price and quickest rate.

We will now touch upon one or two of the more debatable points. (1) Number of impressions in the mould. (2) Trimming. (3) Design of tool and of moulding. Although I can only give brief pointers to most, due to time, and should say at the outset that I shall not really be able to do justice to them.

Let us take these points in order and briefly examine them. Firstly, number of impressions. There are many shades of opinion on this important detail, and papers have been devoted to it. In general, however, if we consider the whole problem we can, I think lay down broadly the lines of logical approach. Let us assume we are given a sample of some article to be produced. With this we can also expect the "sales" to give us (a) quantity required (b) the time period over which this quantity will be spread and (c) the conditions under which it will be required to work. We have thus sufficient data to establish daily or weekly output, amount and type of powder to be used, and total contract duration. It is therefore a matter of figures to set up a reasonable forecast of powder cost and curing cycles which can be regarded as constants. The next step is to decide the size of tool, and in order that we can consider the matter without any limiting features we will assume that an appropriate press will be available.

Co-operation with any good tool maker will enable you to secure prices of tools of varying numbers of impressions, and if we then work as follows—by the trial and error method—we shall find the best resultant.

(1) Powder cost per impression. (2) Moulding cost per impression (based on the size of press under consideration which will be decided by size of job and number of impressions in tool) and (3) tool cost per impression.

It will be apparent that as curing time is a constant, independent of number of impressions, and that labour cost is also a constant, and, further, that as it takes usually only very slightly longer to load and unload a twelve impression tool than, say, a four impression tool, there is a large saving of time in a large tool. To offset this the press is more costly and so is the tool.

If therefore we work out independent sets of figures for say four, eight, 12, and 16 impressions, the overall nett cost per impression will show obviously which is the cheapest combination. Care should be taken, however, particularly on quick curing jobs that the operative has time to reload the next charge, etc., whilst the charge in the press is curing, and here is definite scope for good organising and often for ingenuity.

Every article that is press moulded leaves a raw edge where the upper and lower halves of the tools join, and this must be cleaned off by hand or mechanical means such as machine filing grinding, buffing or rattling, and I am afraid I cannot say more than voice my firm conviction that this is the "Cinderella" department of the majority of moulding firms. It always upsets me to see rows of girls with hand files, in what is otherwise an up-to-date, well organised shop, and yet it is all too often the case. I am convinced that if the same thought and investigation were only given to this

department that is given to the moulding, many changes would be made and detailed investigations into costs would reveal many times that it actually costs more to trim than to produce.

I had a very striking object lesson of this point on one occasion when I was privileged to go through the works of a large trade moulding firm in the Midlands, working both phenols and ureas. The following were the noteworthy features: (1) They had really "got down" to, and, as far as possible, mechanised the trimming. (2) They could make a profit out of work that most firms would turn down. (3) They could pay wages to the operatives far above the average. I will leave this point with the hope that a little said will be more easily remembered and turn to the third point, i.e., design of mouldings.

Let me impress as forcibly as I can that the draughtsman who is given the job of designing a moulding should be "plastic minded," as if he approached the job with a "metal mind" he will probably add to mould cost very considerably and also to moulding cost. He should remember always that the tool will be the reverse of the article, that the article should be formed by direct closing two halves of the mould. Undercuts always lead to expense and external sharp corners, particularly if they are blind, also are to be avoided wherever possible. A simple example of how a costly job from both tool and production angles was avoided is a bobbin, by making in two halves. The whole process was simplified and the resultant was a better job.

I would like to make a plea to all who are considering embarking on "plastics" to "use" the powder makers and the tool-makers, all of whom are ready and willing to give expert advice on their own manufactures.

I would like to say a few words on injection moulding, which to date is confined almost exclusively to the "thermoplastics" i.e., those that will remelt under the application of heat. (In the case of the thermosetting the waste is scrap entirely, but with the thermoplastics the waste can generally be used again). I think this lesser known offshoot is worthy of our best and deepest consideration as I prophesy that in a short space of a few years we shall be injection-moulding the thermosettings. The process is simply the injecting from a nozzle of the materials in the plastic state into a cold mould which can be opened almost immediately and the finished article removed.

The more popular machines comprise, on the one side, a horizontal cylinder, say $1\frac{1}{4}$ in. to $1\frac{3}{4}$ in. internal diameter, surrounded by electric heating lelements and terminating at one end by a diminishing cone into a nozzle, with $\frac{1}{8}$ in. diameter orifice, which is hard against the die or mould. A reciprocating ram, mechanically or hydraulically operated, works in the cylinder. The ram entrance end

(i.e., the opposite end to nozzle) is open at the top to accommodate a hopper feed, by which an automatically controlled charge of powder is introduced. In action, the ram moves forward with a pressure of 1,000 lb. per sq. in., and the taper nozzle acting virtually as a hydraulic intensifier gives the material a nozzle pressure of 15,000 to 20,000 lb. per sq. in. By thermostatic control we can maintain a flow of material at the nozzle at the required temperature. The opposite end of the machine is virtually our four pillar press laid on its side and either hydraulically or mechanically operated.

This mechanism operates the moving die, a centre plate is interposed which carries what is termed the fixed die. When the machine is open the so-called fixed die moves away from the nozzle under spring action about 1 in. to 1½ in. to break the material at the nozzle end, and the moving die carries on until the space between the dies is about 6 in. to 8 in. During the latter half of the opening movement ejector gear operates. The whole action is fully automatic and is adjustable by timing gear.

The fundamental difierence between the thermosettings and the thermoplastics, as outlined by Mr. Jones, is that under the action of heat the former make a chemical change, whereas in the latter case of the thermoplastics we merely melt the materials—"squirt" it into a water cooled mould, open same, eject and repeat.

Let us assume we are producing hair combs. We have two half die plates, each of which has two or four half impressions of a complete finished comb cut into it, with gates or runners connecting each to the feed point. The fixed half die plate has a hole through, corresponding to the machine nozzle, and the moving plate brings its half die up to the fixed die and pushes the two dies, correctly located, into close contact with nozzle and holds them against an opening pressure of 50 to 75 tons. The ram then comes forward, injects the melted material, recedes, and so takes in the next charge, and the dies then open and the finished combs are ejected as explained.

This process is very much quicker than the moulding of the thermosetting, as the only wait is whilst the material is set sufficiently to retain form, and, on such articles as combs, 250 shots per hour can be comfortably maintained and, on certain work, 400 shots can be made.

In conclusion, I would like to place on record my sincere appreciaton of the kindness of Messrs. F. A. Hughes & Co. Ltd., London, for the loan of injection moulded samples, the Barnet Comb Co. Ltd., Welwyn Garden City, for combs, Messrs. R. McArd & Co. Ltd., Denton, for mouldings of lavatory seat and cover, and the Orb Engineering Works, Ltd., Middleton Junction,for the various mouldings and tools.

Discussion.

MR. F. GROVER (Section President) : Before I call on Mr. McMahon to move a vote of thanks, I should like to say that I think you will all agree that we should send a letter to Mr. Jones expressing our regret at his inability to be present to-night, and telling him that, in spite of his absence, Mr. Prior read his paper very well indeed, and that his name will be associated with the vote of thanks.

MR. MCMAHON : The Yorkshire Section are to be congratulated on having a paper put before them dealing with a comparatively new industry. Many of us are not familar with the process of plastic moulding, but we can visualise the wide scope it has in the cabinet trades. We can see the tool makers entering into the cabinet trade in the near future. As a matter of interest, I wonder if Mr. Prior can give us some indication—realising that the industry is at present in its infancy—of the cost of the lavatory seat—a sample of which is on the table—made in plastics as compared with the wooden article, which is made in the cabinet trade. I would like to propose a hearty vote of thanks to Mr. Prior and his colleague, Mr. Jones, for giving us the opportunity of listening to the paper, which we have all enjoyed.

MR. R. J. MITCHELL : It gives me very great pleasure to second that proposal. We are greatly indebted to Mr. Prior for coming along, and I am sure that he need have no feeling of having shown any short-comings during the absence of his colleague, much as we deplore that gentleman's illness.

Several points have occurred to me. I recall that some years ago in a large but most unfortunate works in the South of England—unfortunate in the sense of its financial history—in a secluded corner of the works, secret experimental work was being done. This was none other than a fairly successful attempt at moulding a complete motor-car body in a material which, although having only a slight relationship to the materials we have heard about this evening, nevertheless had the useful property of setting through natural air hardening and drying. I have never heard whether this technique has progressed from the initial stages, but it was quite obvious that possibilities resided therein. A one-piece body, with seats, pillars, and doors, had great potentialities from the sound insulation standpoint and as regards weight.

There are some aspects of the moulding problem which are specially interesting. I have never understood, having once been employed for a time in a very large gramophone works, why the gramophone people go to such apparently needless trouble—I am sure I must be wrong in using that word, but I speak as having

no special knowledge—why they mix such a variety of materials, including natural shellac, which was then about £300 a ton, including lamp black, whiting, and others, so as to make the material from which gramophone records are pressed. Incidentally in the same works the timing of the presses formed the subject of a most intensive controversy among the senior administrative and technical staff. One side disclaimed better results, and the other pinned their faith to it wholly. The engineers ultimately proved to be more than right, and the reduction in scrap as a result of that procedure was extremely marked, whilst correspondingly the maintenance of a uniform standard was equally definite. I should like to know whether any thermo-plastic material is suitable for making gramophone records. It would appear that a material something like the comb shown to us, would possess just those surface properties of low frictional resistance which would be suitable for gramophone records provided a needle were used which was very kind to the surface from the scratching standpoint.

Another point about which I would like information is whether any moulded compounds, excluding ebonite, of course, can be relied upon safely to resist the attack of acids such as weak sulphuric, and, conversely, fairly strong alkalies. I have never understood why ordinary ebonite seems to have such an undisputed hold in the accumulator world.

Mr. Prior: On behalf of Mr. Jones and myself I would record our appreciation and thanks for the kind things you have said, and also for the honour done to the Institute of the Plastics Industry by asking us to prepare this paper for you. I would like to say that I shall consider the finest compliment you can pay to us—Mr. Jones would have said the same—is to ask a lot of questions.

With regard to the lavatory seat, here is one of the exceptions, in that it is a considerably more expensive article than the wood counterpart, but it is more attractive and hygienic. The sample is really to show what can be done. It may surprise you to know that the man who manufactures those is also one of the biggest manufacturers in the North of England of the wood seats, and he sells one not as a competitor but as a complementary item to the other. Speaking generally on the matter of costs, if you have a quantity you can get a lot for your money. In plastics, the material itself is generally round about 8d. or 9d. a pound—even lower on contract—and its weight with a specific gravity of about 1.4 is about half the weight of aluminium. Further, as the articles are finished from the moulds, you can get a lot for 1s., whereas as engineers you will agree that you cannot do very much in an engineering works for 1s. On that count alone it is worthy of your consideration, and it is worthy of your looking a little further than that on the question of tool costs. You will realise that if we are to impart to the moulding

the finish we require, the moulding must be excellent and the cost is, of necessity, high. The multiple tools, of course, go higher again, but as against that the injection trade have shown us that we can cut down cures and, as I said in my paper, I am absolutely convinced that injection moulding, or, at any rate, a very close cousin, will shortly come into being and do away with all our tools. I was told only two months ago by a director of one of the largest powder making firms in this country that they have now ready to market powders which will cure in one to three or four seconds, as against minutes, usually the time one allows, but it is now for the engineer to come along and bring out the plant to work on these rapid cycles.

Mr. Mitchell raised the question of the air-hardening moulding material for the motor-car bodies. Frankly I have never heard of it, so I am afraid I cannot say much about it. With regard to the gramophone records, and the questions on acids, perhaps Mr. Hill can do more justice to them.

MR. A. HILL: With regard to Mr. Mitchell's question about gramophone records, one can safely say that, up to date, nothing has satisfactorily replaced natural shellac as the binding material for ordinary gramophone records. For special purposes recordings are made on steel, but I would like to point out that thermo-plastic materials—viz., cellulose acetate, which has been referred to by Mr. Prior, has been tried, but without success, since its wearing properties are below the standard necessary for this kind of work. The properties of natural shellac products have undergone considerable improvement since the early days of gramophone records, owing to the vast amount of research work which has been done on the material. I do not think anything is likely to supercede it for this type of work.

With regard to the acid and alkali resistance of phenol-formaldehyde resin products. In the case of batteries, as one example, bitumen has been used as a binding material for a long time, but phenol-formaldehyde resins can be used with success and will stand up to the work as well as, if not better than, vulcanite. With alkali the resistance can be considerably improved by the use of mineral fillers, such as asbestos, etc.

The types of air-hardening materials are the bitumen—linseed oil types, which are naturally air drying on account of the nature of the binding materials. They are now little used and are redundant in the industry. Generally speaking, the plastics of the phenolic types are resistant to dilute acids, but are not advised with use in connection with alkalies. The main types which are alkali resistant are the aniline formaldehyde resins and others of a special nature—e.g., vinyl chloride polymers, etc., such as Mipolam and the like. In accumulator work ebonite is well established on account of

price, acid resistance, weathering stability and reasonable strength. Shellac compositions are still the most popular types for the manufacture of gramophone records for the following reasons: They are tough and resist the erosive action of the needle; very plastic at the moulding temperature and take fine impressions with ease; and have a good surface hardness and take an excellent finish, etc.

(Members then inspected the various samples of mouldings brought by Mr. Prior.)

A VISITOR: I call myself a chemical engineer, a definition of which is a man who talks chemistry to engineers and engineering to chemists. Asbestos formaldehyde mouldings were shown as having an electrical strength of 250 to 400 volts. My impression is that this is very optimistic. From the samples I have handled—and the same applies to the power factor—my idea is 30 to 40 volts. I should like to know whether Mr. Prior can give any details of these moulding powders which will cure in one to five seconds. Are they thermo-setting? We should like to use them as they have a good deal of advantage over the slow-moulding products. On the question of thermo-plastic materials, have they good mechanical strength in the cold, even if subjected to continued pressure? Finally, how does the cost of plant for making a thermo-plastic moulding compare with that for thermo-setting moulding?

MR. PRIOR: With regard to the stresses mentioned, they are fairly sound, and I would suggest to you without trying to avoid the questions at all, that we are perfectly happy if your mouldings were thoroughly good in every sense. It is one of these points where an apparently good job, when you come to ask of it certain specific qualities, very often shows a lack of moulding technique or shows flaws in the sense that it is not a perfectly moulded job. You take a lot of the articles which are sold—such as chain-store articles. They have done more to earn our industry a bad name than anything, in that they look good, but they are not thoroughly cured out. Whether you are referring to that type of article I do not know.

VISITOR: I am speaking of articles we have actually produced ourselves, which we believe to be cured, having shown up badly under very severe conditions—conditions of unknown severity. I have seen it stated that the values of yielding points cannot be taken as a fair criterion.

MR. PRIOR: I am inclined to agree with you that on thermo-settings we get a very short, a brittle, texture. Their strength is low. You can only compare them to metals in the way of, perhaps, cast-iron, which is notoriously low in tensile, and you have to consider them in that light. There is no ductability figure with the thermo-settings. You get more with the thermo-plastics, but, of

course, their ultimate tension is considerably lower. Regarding cold flow, you may get a tendency that way. As engineers, we are all apt to overdo our requirements in the sense that plastics are not intended to replace metals. They are intended to go along with metals where the application is good.

This question of quick curing powders sounds good, but can you use them if you get them ? If you get a powder that is going to cure in five seconds, at the very nearest it will take you three seconds to close the press. Actually, I do not think that the presses can use these rapid powders. That is, I think, where the engineers have to come in. Another thing is that the question of storage is going to come into account, because if a moulding material has got such accelerators in it that it will run at that speed then you will have to control its storage temperature. That is a problem. I do not know of any of the most modern presses, even the quick-acting presses, where you can take advantage of these rapid flows, but you can take it quite definitely from me that it was spoken at a meeting of the Plastics Institute a short time ago, where one of the directors of one of the biggest firms in this country said that they had the powders ready when the trade was ready to use them.

With regard to the question of the cost of plant. You are embarking on a very broad point. One cannot generalise on the cost of plant, but the machine I showed you cost about £1,200. The Zeigler is somewhere in the region of £800/900. A press of 75 to 100 tons with its gear may cost you as much, but you would have the disadvantage that the raw material would cost you more, so that it might come out somewhat cheaper in that sense, but if you were to work it out from the standpoint of productivity, I do not think you will find a big lot in it, except this, that you can manage with a considerably smaller tool for the same output, and when all is said and done your press on the one hand, or your injection moulding machine on the other, is a capital charge, whereas your moulds are not, unless you are fortunate enough to get your customer to pay for them. There is no doubt that the rapid cure is going to show a very definite saving in that sense, but it is very difficult to generalise on that point.

The figures given showing the electrical properties of the various plastics were taken principally from the data furnished by the American makers—see Modern Plastics—October, 1937. Figures covering the main plastics used in this country are given in comprehensive fashion in the Electrical Review of January 21, 1938, in a paper by Blakey. Here the figures for an asbestos filled phenolic material are 200 volts per mil and 0.2 — 1.0 as breakdown voltage and power factor respectively.

On the question of materials which cure in a matter of seconds,

these are for special work and are useless in standard pressure moulding, which is a relatively slow operation. Rather are they designed for the future when injection moulding and rapid rotary pressure moulding of thermo-setting products is sufficiently advanced from an engineering point of view.

On the question of the mechanical strength of thermo-plastic materials in the cold, I would refer again to Blakey's paper which gives full details on this point. B.S.S. 771 of 1938 also gives full information on the figures obtainable with phenolic materials. It might be mentioned that most thermo-plastics show a Martens softening point of about 80°C. This is the temperature at which a moulded bar shows a 6 mm. deflection under standardised conditions of test.

MR. SMITH: I am interested in the industry. The greatest expense, as far as I know, is the time during which the powder is cured, because your factory charge is going on all the time. Is there any definite time as to when a mould is fully cured, or is it like cooking, where one person likes it well done and another person over-done? The whole point is when is it just cured, or are you taking it half a minute or a minute and a half too long? I raise this question because I have often to decide when moulding is cured, and as far as I have been able to find from the industry they cannot tell me. Can you tell me?

MR. PRIOR: Yes, I can. There is a definite point where a moulding is cured. It is not a question of having it under-done or over-done. As soon as you come on to the under-done side then you have an imperfect moulding. To a degress, perhaps, but not so pronounced on the other side you have an imperfect moulding if you over-do it. There is a margin you can allow a moulding after it is fully cured, to stay on the press without deterioration, but it would be very difficult to conceive a powder which would cure out, shall we say, $^1/_{16}$ in. wall and an adjacent $\frac{1}{4}$ in. wall and make them together, at the same time, so that the powder must carry some flexibility. There is definitely a point where a powder is cured, and I am rather surprised as to why you say you had difficulty, because to the best of my knowledge all you need to do is to go to any powder maker of repute, put up your worries to him and tell him you cannot get away with his stuff, and he will send someone to help you, and if you have a moulding which is apparently good and you are not happy with it, I am sure the powder maker will get down to it and tell you whether it is good or not. They have the facilities for test.

MR. SMITH: How do you tell when you take a powder out whether it is fully cured or not? Is it possible, after taking out the mould to say whether the thickest portion is just fully cured or whether you have given it too much, because the time is very valuable?

MR. PRIOR: Yes. I do not think it will be very long. In your own works you know it is always the easiest thing to take the moulding out and cut it in two and say whether it is perfect or not, but once you have found a balance—for instance, as I said in the paper—to start a mould take plenty of powder and plenty of time and to get the weight correct is, as you realise, pretty easy. You go on until you have these flash marks and you bring your time down in 15-second stages until you begin to get obvious signs of undercure, or the moulding is soft and so forth, and then you go a little bit beyond that. You have, at any rate, a rough and ready idea that your moulding is pretty good. It is not a big job then to run off half a dozen specimens such as you think are good and send them out for test. Then you have that data which is there for the next job and actually that is the general method. If you are asking for an academic rule, there is no academic rule. The standardisation of powders is definitely having a lot of attention, but we are not yet so far advanced in the industry that one could give you a rule or a formula which would answer your problem 100%.

MR. SMITH: I know you can cut open mouldings and find they are apparently perfect inside, thoroughly baked and with no change of colour from the outside to the centre. I have known those mouldings to burst after having been in service, due to climatic conditions. What I was really asking was, is it possible to drill out a portion of the thickest part and give it any chemical or scientific test to say that it is cured? What are you purchasing when you have finished? You can see the outside of the article but not the inside. Can you scientifically test inside to find that it is a perfectly cured moulding?

MR. PRIOR: I should say the instance you give of mouldings bursting is due to too high a temperature or too low a curing time. That actually is what once happened in the case of some very cheap door knobs which were stuck on doors, and after ageing for some time they burst, but that was not the fault of the mouldings in the real sense. It was the fault of the manufacturer wanting to get them off cheaply and cut down the curing time and increased pressure. Your instance of bursting would point a line in that direction.

To get the real answer to your point—from your question I understand it is not a touched up article but one which you have honestly attempted to make perfect and then found after ageing is imperfect—I am afraid I cannot, and I do not think anyone in the industry could, offer you any academic formula, as, quite frankly, there are too many factors which could possibly contribute to that point, and the industry has not yet grown to that stage. We are coming to it and are trying to get nearer to the ideal. I am afraid I cannot offer you any real data which you can take away with you.

I must say that your point is one which is unusual. My view is that experience tells and my suggestion is for you to get hold of a good consultant who knows the business. It is very surprising how much farther he can take you along the line.

Two methods are available for the determination of the degree of cure of a thermo-setting composition. One is to determine the plastic yield point either according to the Martens test mentioned previously or, alternatively by the test outlined in B.S.S. 771 of 1938. This test can be adapted to suit other designs of mouldings than a simple bar, and provided that the tests are carried out under standardised conditions the results can be very useful. For the effects of extension of the time of cure with phenolic materials I refer the speaker to Transactions of the Institute of the Plastics Industry—No. 12, p. 79, where it is shown that prolonged moulding periods can increase the Martens softening temperature of a phenolic composition from 130°C. to 160°C. This surely affords a means of determining the degree of cure.

The B.S.S. 771 referred to describes a test for the determination of degree of cure by taking from any moulding a sample,—e.g., by drilling or filing, etc., and carrying out an acetone extraction test. The specification in question states that the amount of acetone soluble material so prepared shall not be greater than 6%—which actually is quite a high figure. Most commercial mouldings when so tested would show better figures than this. It is quite obvious that methods are available for the determination of the degree of cure of a material, but unfortunately they are not in such widespread use as one would desire.

MR. NEWELL: Apparently the people selling the powder do not know what it is they are selling, and they do not know what it is they have to finish up with. That is the experience of our friend over here. If I am wrong I would like to be put right. Apparently the people who are handling the powder do not know what it is they have to test. They do not know the chemical formula or the substance they finish with. Am I right?

MR. PRIOR: No, you are wrong. It is a very sweeping statement to make, and from the remarks of Mr. Smith it would possibly give colour to and give weight to your remarks, but I would ask you to remember this. When one has got the powder and one cures it you can go wrong on quite a lot of points and spoil a perfect product and whilst the powder makers can answer for their manufactures they certainly cannot answer for inexperience in use. We have not by any means said the last word on the correct production or use of the material. I am quite prepared to admit that possibly some of our methods are crude compared to metals. Really our methods right through the industry have a long way to go before we have got to the ideal. I am prepared to agree and to admit that, so far,

the engineers have rather lagged behind the powder makers. I would not place the blame at the door of the powder makers. If you can specify what you want and state how you will treat it, they will give you a job.

MR. NEWELL: That does not explain the whole thing. I understand you cannot give Mr. Smith a formula to enable him to examine his finished product.

MR. PRIOR: No, but the powder makers can.

A MEMBER: We can test steel and say whether we have the proper treatment. We know whether we have the right result. What about bakelite?

MR. PRIOR: There is one thing you have forgotten and that is that the materials we use make a chemical change in the mould. You can see they give varying factors. We can effect or affect results even with a perfect powder.

A MEMBER: Cannot you analyse the material and tell where the change has taken place?

MR. PRIOR: I would not like to say, but Mr. Smith's point is a remarkable one and one which is not often come across. In my opinion Mr. Smith's trouble is one of too high a temperature. Far more is known about chemical constitution and properties of these materials than would appear from his remarks. Again, it is unfortunate that many firms are moulding materials which are produced to meet cut prices and it is inevitable that some valuable property must be sacrificed. The fact that plastics have attained the dignity of having their own special British Standard Specifications is ample proof that consistent working to high standards is now a reasonable demand. (See B.S.S. 316 and 547 of 1934, 488 of 1933 and 771 of 1938).

MR. F. GROVER, M.I.P.E. (Chairman): We have had a very breezy discussion at the end, which I understand Mr. Prior was actually looking for when he came here. Now he must be satisfied! Whatever has been said, we still appreciate the way in which he has stood up to the stresses himself!